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CABIN HAZARDS FROM A LARGE EXTERNAL FUEL FIRE ADJACENT TO AN AI--ETC(U)
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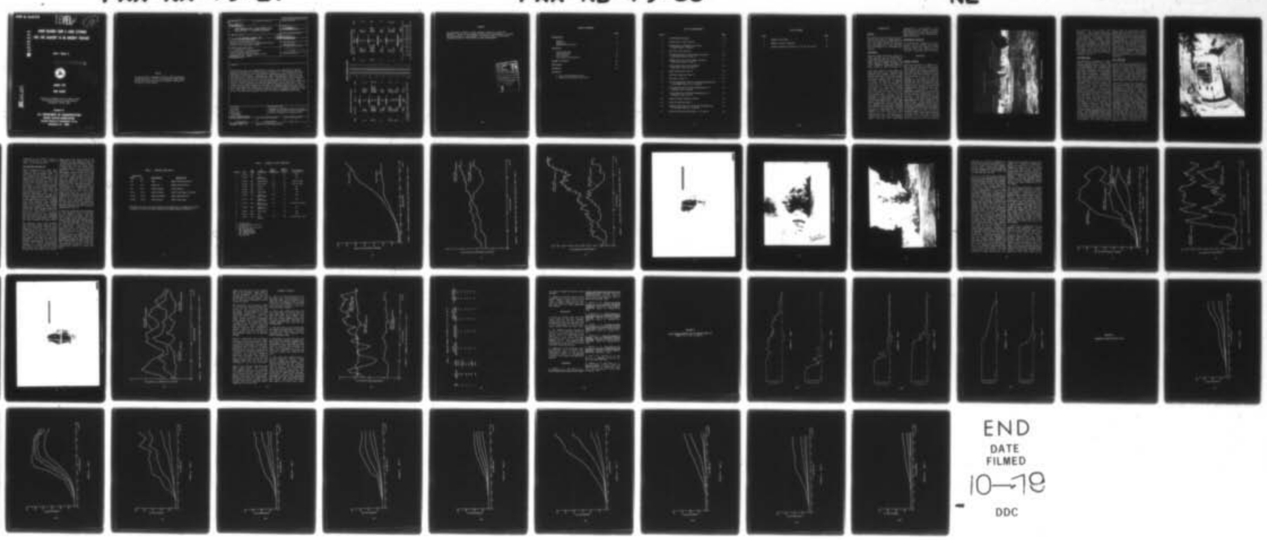

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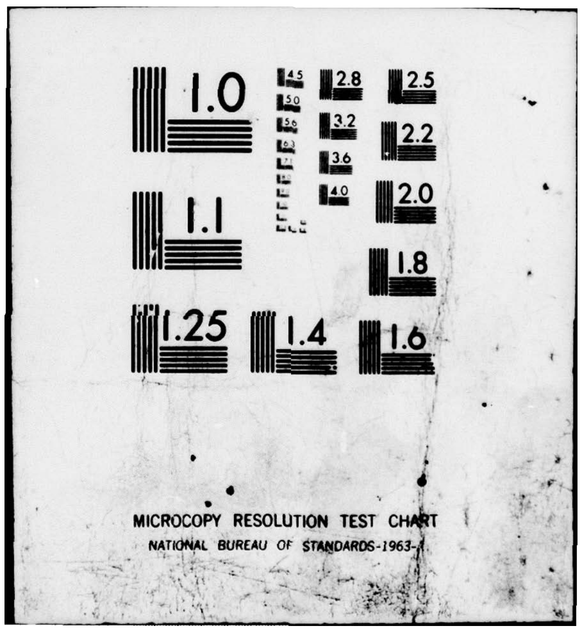
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REPORT NO. FAA-RD-79-65

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CABIN HAZARDS FROM A LARGE EXTERNAL FUEL FIRE ADJACENT TO AN AIRCRAFT FUSELAGE

Louis J. Brown, Jr.

AUGUST 1979

FINAL REPORT

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16. Abstract

Fourteen fire tests were conducted with a surplus, fire-hardened DC7 fuselage positioned adjacent to a 20-foot-square JP-4 fuel fire. The fuselage had a door opening at the center of the fire and door openings displaced from the fire on each side of the fuselage. Temperatures, light transmittances, and heat fluxes were measured for each of these 90-second tests. The opening of doors away from the fire was varied from test to test as was the ambient wind velocity. Wind direction coupled with the door opening configuration were found to be controlling factors in the accumulation of heat and smoke within the aircraft cabin. Heat fluxes into the cabin through the fire door also changed significantly with wind and door openings and depended on the degree of flame penetration through the fire door. When flames did not penetrate into the cabin, the symmetry plane heat flux at the fire door station agreed very well with earlier modeling predictions.

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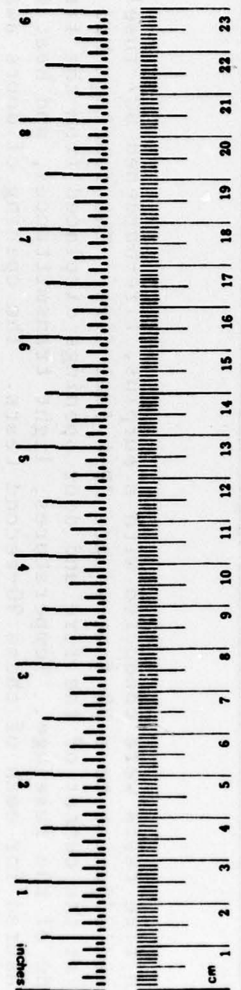
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

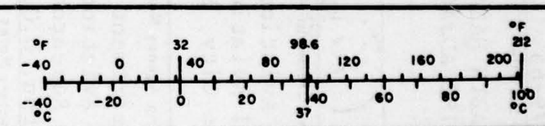
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The assistance of Messrs. Joseph A Wright, Franklin D. Fann, and Lawrence J. Curran in the varying activities of instrumentation, testing, and data analysis is acknowledged. The helpful advice of and useful discussions with Dr. Thor Eklund are also acknowledged.

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INTRODUCTION

PURPOSE.

The purpose of this project was to measure and study the flame penetration and resulting accumulation of heat and smoke inside an aircraft cabin produced by a large external fuel fire adjacent to a fuselage door opening.

BACKGROUND.

During an impact-survivable crash, the cabin interior can be threatened by a possible external fuel fire. Heat, smoke, and toxic gases may enter the cabin through fuselage openings and create hazardous conditions within a short period of time (reference 1).

Full-scale tests on the effect of large pool fires on a fuselage have produced heat transfer rates to the exterior as high as 13 British thermal units per foot squared second (Btu/ft^2s) (reference 2) in one set of tests, 16 Btu/ft^2s in another (reference 3), and 18 Btu/ft^2s in tests on a titanium fuselage (reference 4). These heat fluxes are upper extremes that can be realized from a large fuel fire. Wind conditions, door opening configurations, breaks in the fuselage, or "burn-throughs" can be expected to cause great variability in the cabin hazard levels. The cabin hazards resulting from a small fuel fire adjacent to an intact fuselage door opening have been more recently studied at the National Aviation Facilities Experimental Center (NAFEC) in full-scale C133 tests (reference 1). Physical fire modeling tests were also performed to examine the C133 cabin environment under large fuel fire conditions (reference 5). A full-scale test as reported herein was needed to confirm and validate heat and smoke measurements obtained in other modeling and small-scale tests.

EXPERIMENTAL OBJECTIVE.

The experimental objective of this project was to conduct full-scale tests to study the effect of large external pool fires adjacent to an aircraft fuselage door opening.

DISCUSSION

GENERAL APPROACH.

Tests were performed at NAFEC's airport fire test site utilizing an existing 400-ft^2 fire pit. A stripped-out, surplus DC7 fuselage (previously first used by Marcy (reference 6) for aircraft interior materials testing) was prepared as a test article (figure 1). To preserve the aluminum fuselage for more than one test, the aircraft skin was "fire-hardened" with galvanized steel sheeting (0.032 inches thick) placed over Kaowool® noncombustible aluminosilicate fiber blankets (1 inch thick). The fire hardening extended 20 feet on either side of the fire doorway from the top to the bottom centerlines of the fuselage. Two additional doorways were cut on each side of the fuselage approximately 30 feet forward of the fire doorway. These doorways were fitted with removable metal covers. This was accomplished for the purpose of varying the door opening configuration from test to test. All three doorways measured 28 inches wide by 56 inches high. These door dimensions properly scale the Type A doorway openings in the C133 (76 inches by 42 inches) and fire modeling

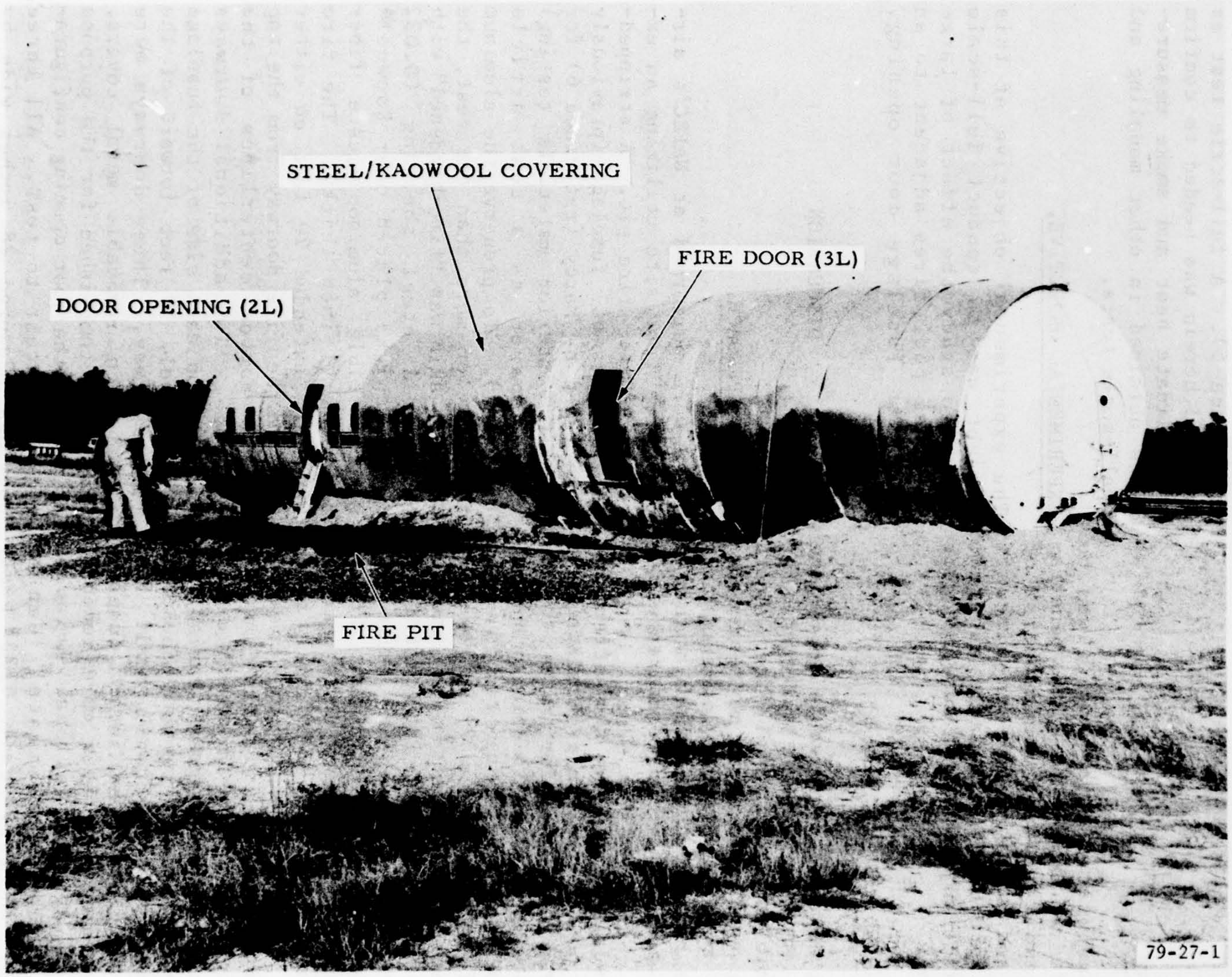

FIGURE 1. FIRE-HARDENED FUSELAGE

(19 inches by 10.5 inches) test articles. The interior was fire-hardened to varying degrees (depending on the proximity to the fire door) using Kaowool, fiberglass cloth, galvanized and stainless steel sheets, and transite. Extra effort went into stripping out combustible materials (insulation, hatracks, etc.) especially on the fire side of the fuselage. The test article was positioned with the fire doorway at the center of one side of the firepit (figures 1 and 3).

INSTRUMENTATION.

Instrumentation consisted of calorimeters, thermocouple trees, laser transmissometers, motion picture and still photography, and a windspeed and direction indicator. Laser transmissometer, windspeed, and calorimeter data were recorded on a Honeywell model 1858 oscillograph. Thermocouple data were recorded on an Esterline Angus model D2020 digital data logger. Both recorders were located in an instrumentation trailer near the fuselage. Plan and side views of the cabin interior show calorimeter, thermocouple, and laser transmissometer locations (figure 3). Three calorimeters (Hy-cal model C-1300-A) were installed at locations that correspond to those of the C133 and physical fire modeling test articles. These locations include the ceiling (C2), exterior skin (C3) (adjacent to the fire doorway), and the symmetry plane of the doorway (C1) (figures 2 and 3). Two thermocouple trees, each consisting of four chromel-alumel thermocouples, were used to record temperatures within the cabin. Two helium-neon laser transmissometers were mounted horizontally at different heights to span a 3-foot cross-section of the cabin (L1 top and L2 bottom). The lasers (Spectra Physics model 155, wavelength = 632.8 nanometers) and photocells (Weston model 856 YR) were covered with fiberglass cloth over Kaowool blankets for protection from the harsh environment (figure 4). A Trade-Wind cup anemometer (model 110) was positioned next to the instrumentation trailer and used to record wind velocities continuously on the oscillograph. Wind direction was manually recorded from a Taylor Windscope (model 3105) direction indicator. Four motion picture cameras were used to document the tests.

TEST PROCEDURE.

A set routine was followed in preparing for and conducting each test. The fire pit was first filled with water to a depth that sufficiently covered the gravel bed. One hundred gallons of JP-4 fuel was pumped from a fuel tanker truck into the pit. Calorimeter cooling lines were checked for proper water flow and laser transmissometer windows were cleaned.

Calibration checks were performed on the oscillograph and thermocouple recorders. Firemen prepared for extinguishing the fire. With all instruments operational, a signal was given to first start the motion picture cameras and then to light the fire pit with a torch. Test duration was 90 seconds, at which time a signal was given for the firemen to extinguish the fire using light-water. Although a longer test duration may have been desirable, 90 seconds was adequate to allow for the development of cabin hazard level conditions reflecting wind and door opening configurations and was believed not to unduly jeopardize the test article. The fire pit was then pumped out to prepare for another test. Repeated early morning tests were

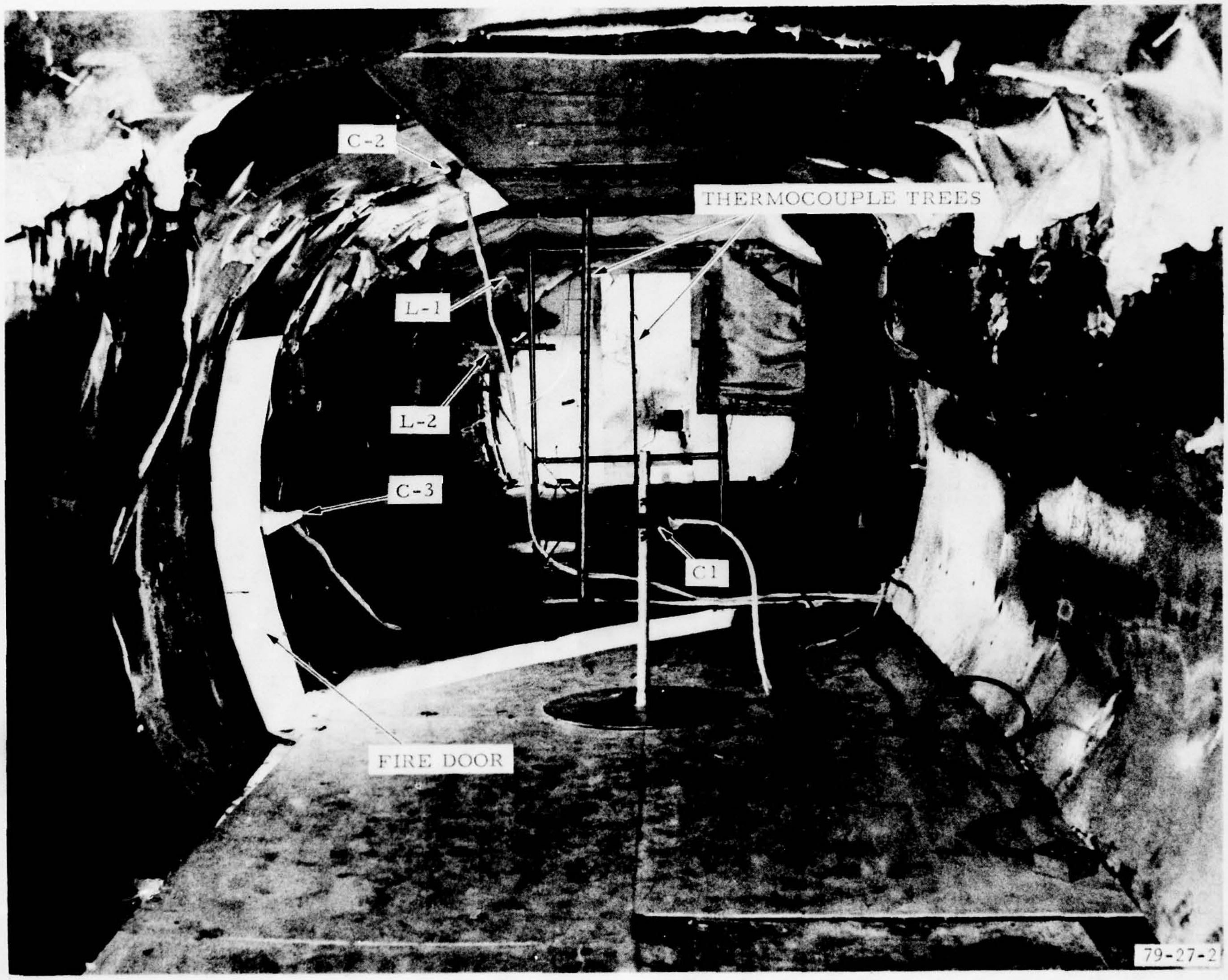

FIGURE 2. FORWARD VIEW OF DC7 INTERIOR

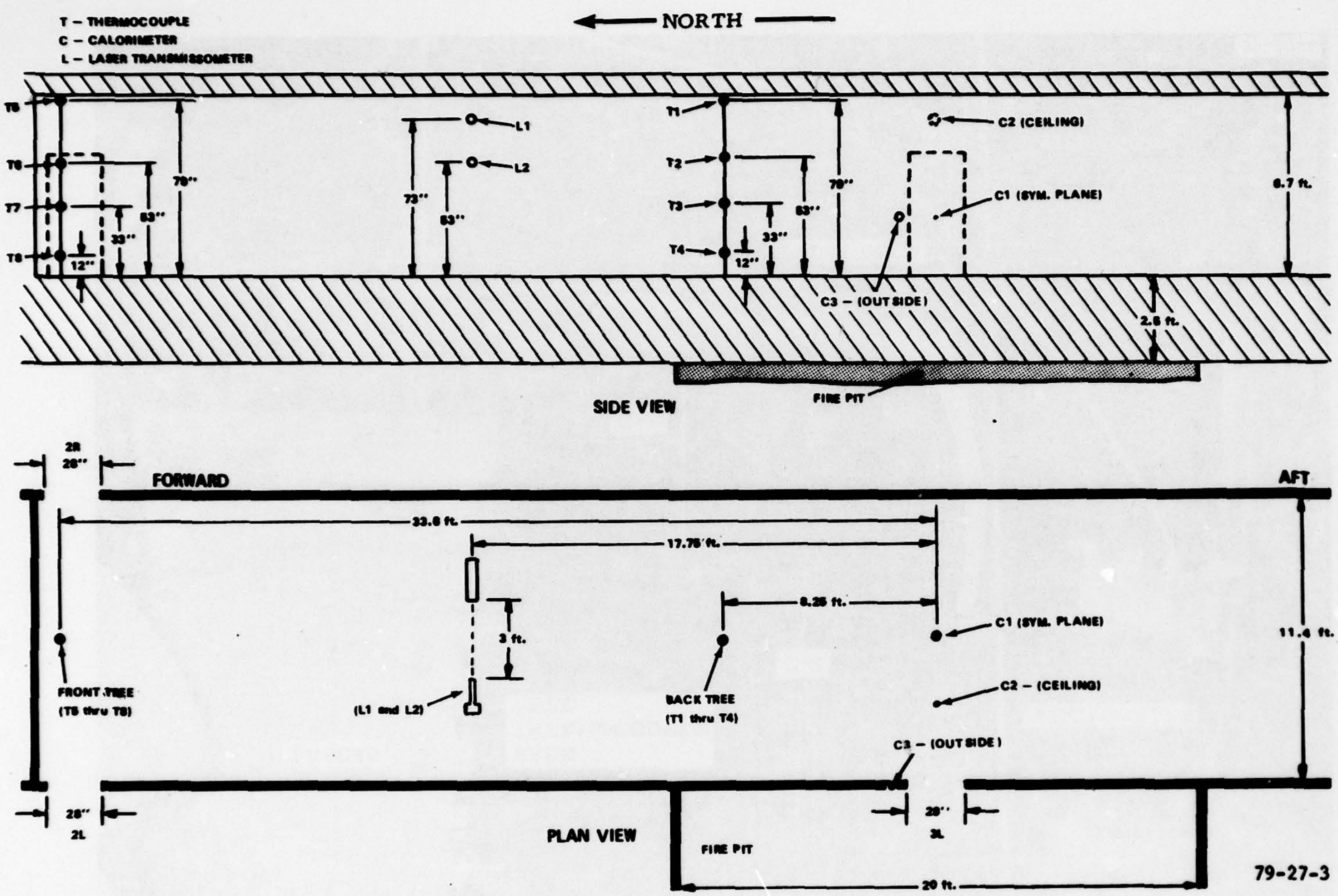

FIGURE 3. THERMOCOUPLE, CALORIMETER, AND LASER TRANSMISSOMETER LOCATIONS

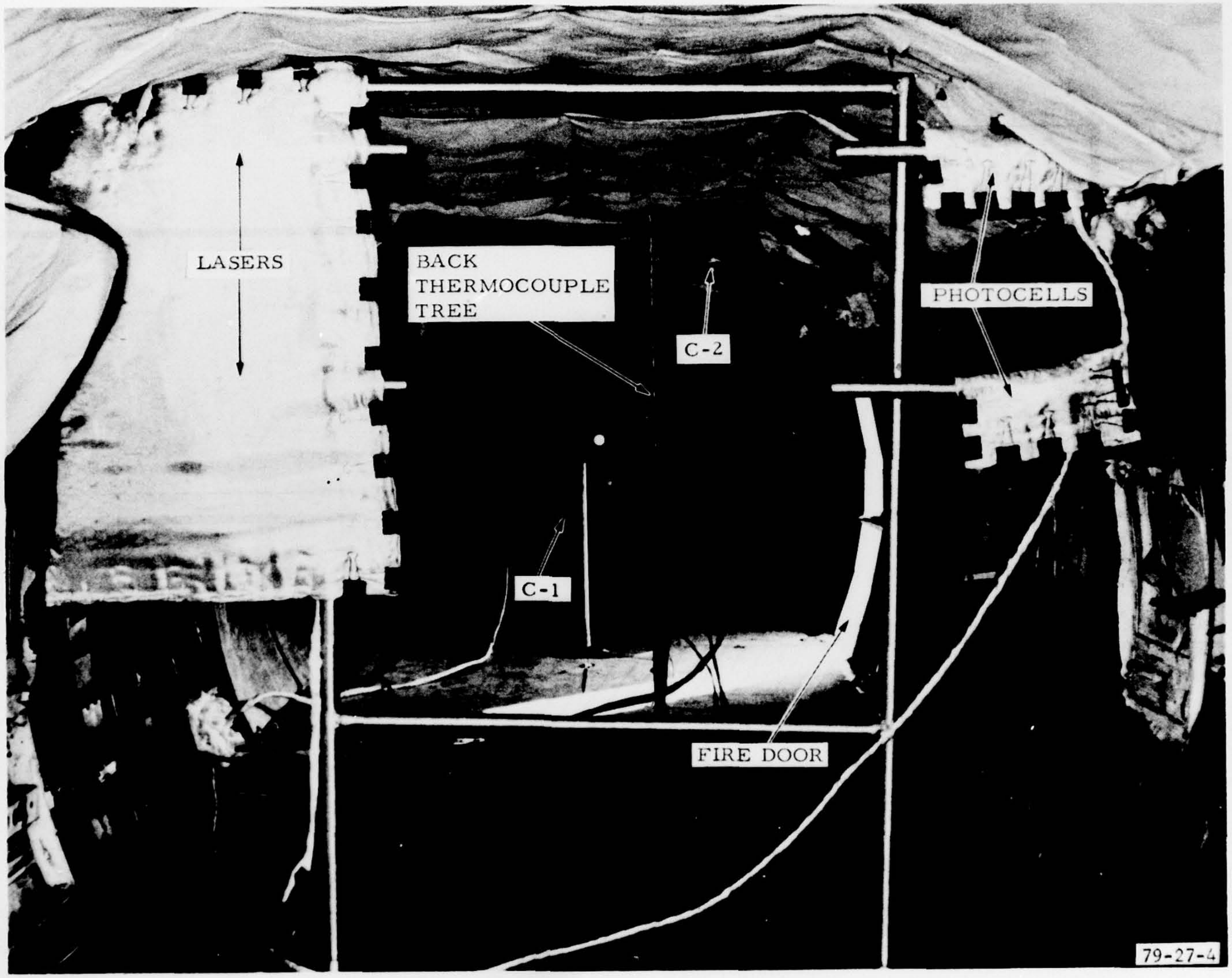

FIGURE 4. AFT VIEW OF DC7 INTERIOR

conducted in an attempt to obtain a calm (reference 7) wind condition (table 1) for baseline data.

TEST RESULTS AND ANALYSIS.

Table 2 summarizes the initial conditions of the 14 tests which were conducted during November 1978. In one category of tests, the cabin hazard levels were low compared to the remaining test results. These low results were obtained when the wind direction was parallel to the fuselage. Peak symmetry-plane heat flux was less than 1.2 Btu/ft^{2}s, and peak ceiling temperature at T1 (figure 3) was less than 200 degrees Fahrenheit ($^{\circ}$F). A test with the wind blowing the fire in a direction away from the fuselage (test 8) also produced low results similar to the parallel wind tests. It became clear from observers' tape recorded reports and exterior movie coverage that the fire doorway was visible during this category of tests, indicating that cabin exposure conditions were not representative of a realistic, large fire. Fuselage skin calorimeter (C_3) output averaged less than 5 Btu/ft^{2}s, thus confirming the low cabin environmental readings that were recorded for these tests.

The remaining tests, which produced significantly higher hazards, fall into two categories. One of these categories is the calm wind condition during which test 13 (all doors open (ADO)) and test 14 (all doors closed (ADC)) were conducted. Significant differences in heat accumulation for these two tests are apparent in the plot of the rear ceiling thermocouple's (T1) outputs (figure 5). Cabin temperature continued to increase when the doors were open, but leveled off at 50 seconds when the doors were closed. These same trends can be seen in the responses of the symmetry plane and ceiling calorimeters (figures 6 and 7, respectively) and the light transmittance data for the bottom laser transmissometer (see appendix A page A-3). It is evident from both photography (figure 8) and the ceiling calorimeter data that there was significant flame penetration during test 13. Smoke and heat filled the cabin and vented out of both forward doorways (figure 9). Test 14 experienced much less flame penetration, as evident in the ceiling calorimeter data (figure 7). Subsequently, less accumulation of heat and smoke occurred during test 14 as compared with test 13. A fire whirl (reference 8) developed during test 14 (figure 10) causing intense radiant heat to be felt by test personnel. However, skin calorimeter output at the fire door for test 14 showed that the fire whirl did not appear to have adversely affected the test results as compared with test 13.

A numerical integration was performed on the symmetry plane calorimeter plot for these two tests. The heat fluxes from 20 seconds (time when fire becomes fully developed) to 70 seconds (time when most readings began to dropoff) averaged 2.4 Btu/ft^{2}s and 1.8 Btu/ft^{2}s for tests 13 and 14, respectively. A heat flux of 1.8 Btu/ft^{2}s was obtained during modeling tests for an "infinite" fire under quiescent wind conditions (reference 5). A higher average symmetry plane heat flux for test 13 is attributed to the flame penetration documented during the test which was significantly greater than in test 14. The variation in door opening configuration appeared to be the controlling factor in these two tests.

TABLE 1. BEAUFORT WIND SCALE *

Windspeed mi/h	kn	Description	Observation
0-1	0-1	Calm	Smoke Rises Vertically
1-3	1-3	Light Air	Smoke Drifts Slowly
4-7	4-6	Slight Breeze	Leaves Rustle
8-12	7-10	Gentle Breeze	Leaves and Twigs in Motion
13-18	11-16	Moderate Breeze	Small Branches Move
19-24	17-21	Fresh Breeze	Small Trees Sway

* Beaufort wind scale is used because of its simple way in defining the minor variation in wind velocities encountered during testing (reference 7).

TABLE 2. SUMMARY OF TEST CONDITIONS

Test No.	Date	Time (EST)	Wind Condition (1)	Wind Direction (Degrees) (2)	Ambient Temperature (F)	Door Configuration (3) (4) (5)
1	11/15/78	0636	calm	---	57	ADO
2	11/15/78	1046	slight to gentle breeze	0	65	ADO
3	11/18/78	0950	moderate breeze	270	55	UDO (2R closed)
4	11/18/78	1249	gentle breeze	270	68	DDO (2L closed)
5	11/19/78	0655	light air	315	34	ADO
6	11/20/78	0621	light air	0	38	ADO
7	11/21/78	0623	slight breeze	0	41	ADO
8	11/21/78	1427	slight to gentle breeze	060	57	ADO
9	11/24/78	0621	slight to gentle breeze	270	56	ADO
10	11/24/78	1054	gentle to moderate breeze	270	64	ADC (2R and 2L closed)
11	11/26/78	0652	light air to slight breeze	0	34	ADO
12	11/28/78	1003	slight breeze	0	43	ADO
13	11/29/78	0630	calm	---	31	ADO
14	11/29/78	1406	calm to light air	270	49	ADC (2R and 2L closed)

1. Reference table 1
2. Aircraft nose heading north (0°)
3. See figure 3
4. Fire door (3L) open for all tests
5. ADO - All Doors Open
   UDO - Upwind Door Open
   DDO - Downwind Door Open
   ADC - All Doors Closed

-- Not applicable

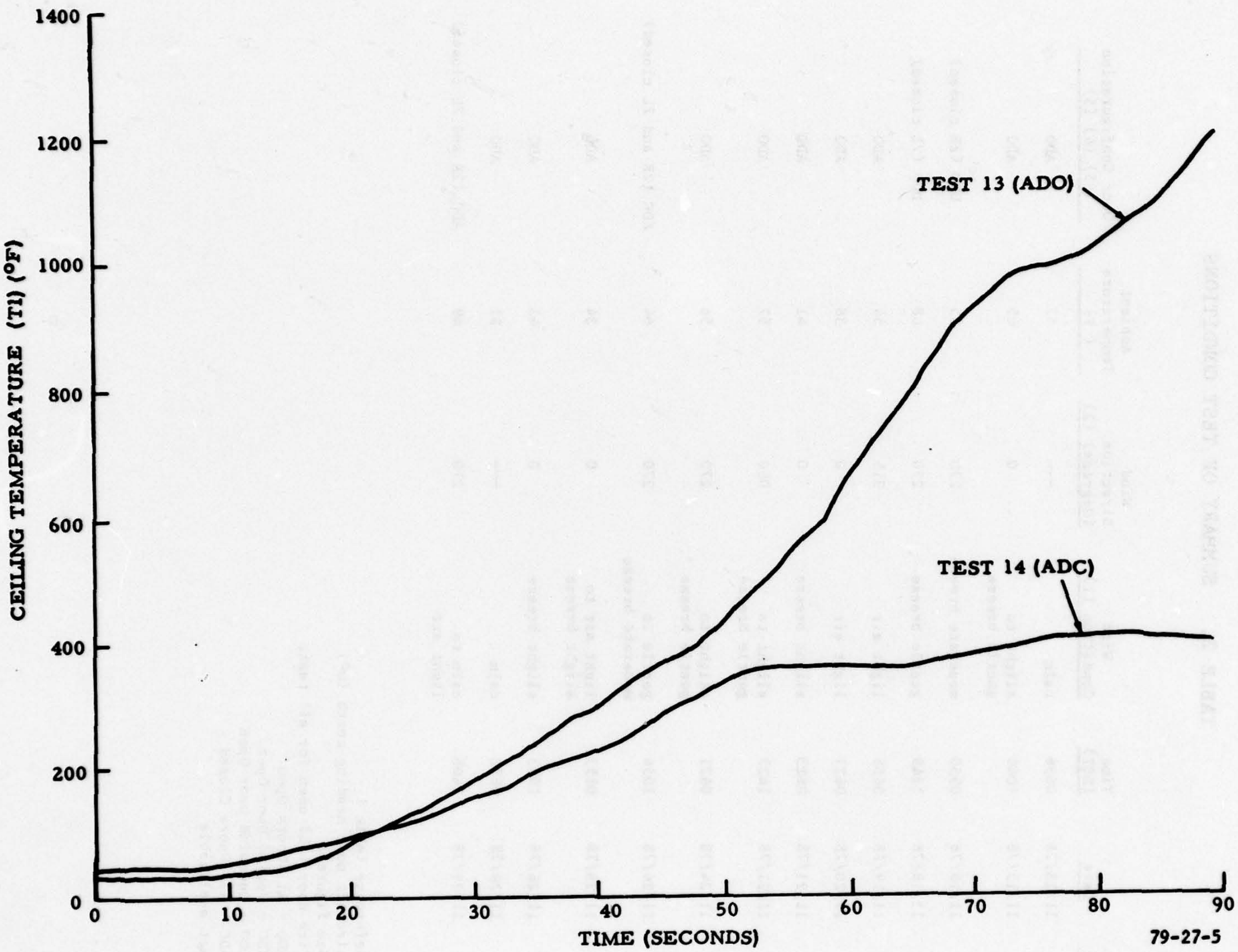

FIGURE 5. CEILING TEMPERATURE HISTORY UNDER CALM WIND CONDITIONS--TESTS 13 AND 14

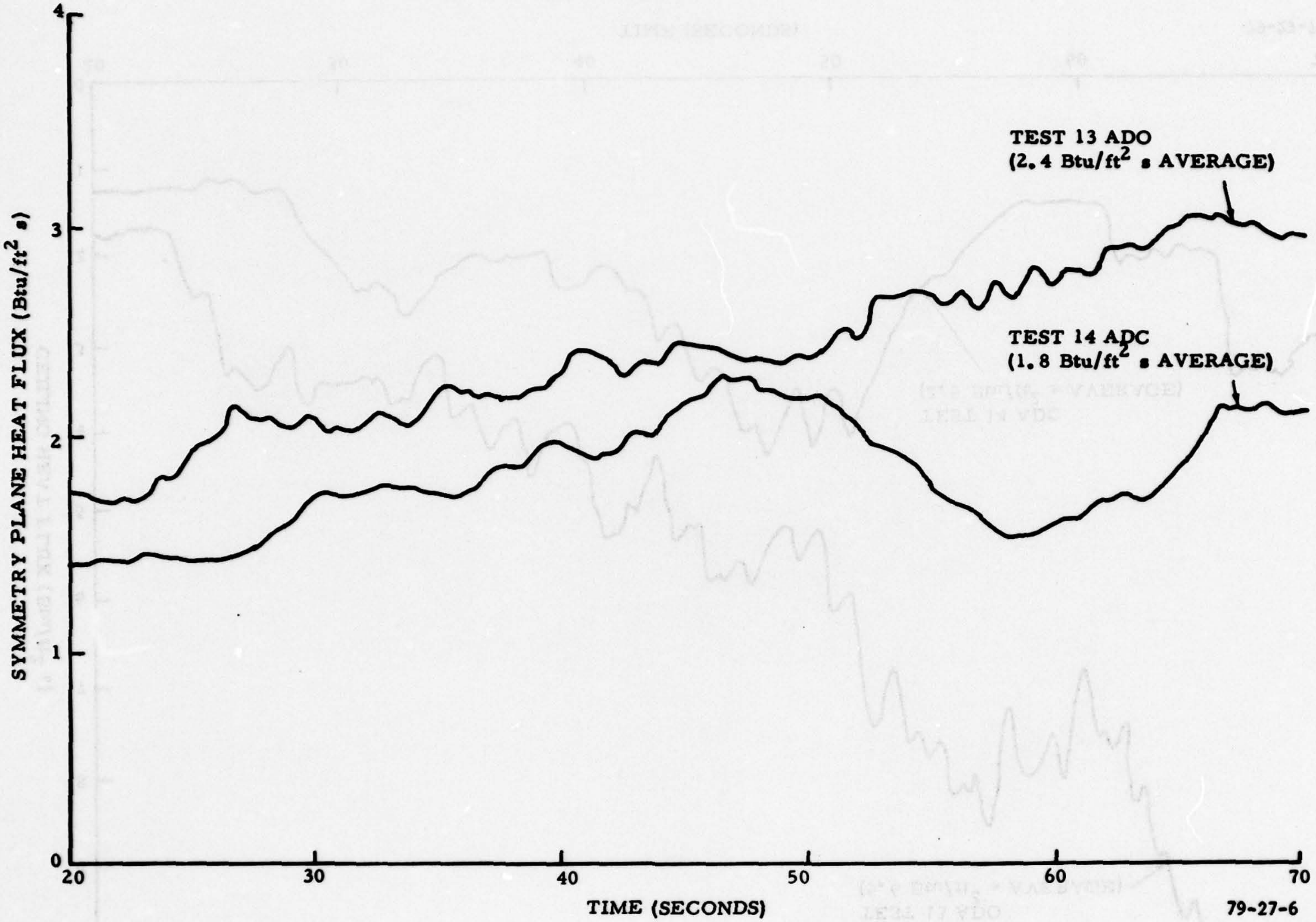

FIGURE 6. SYMMETRY PLANE HEAT FLUX UNDER CALM WIND CONDITIONS--TESTS 13 AND 14

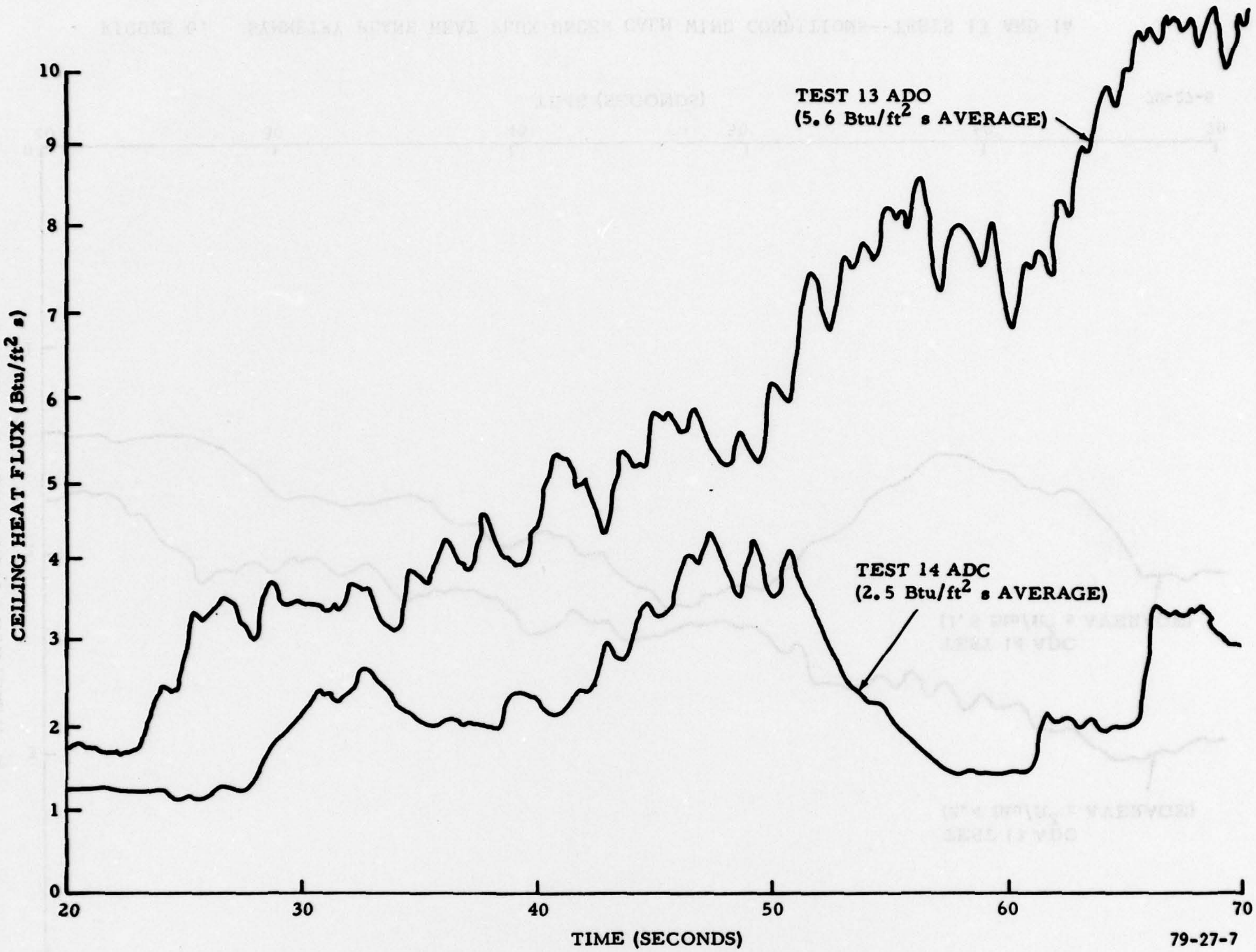

FIGURE 7. CEILING HEAT FLUX UNDER CALM WIND CONDITIONS--TESTS 13 AND 14

FIGURE 8. FLAME PENETRATION--TEST 13

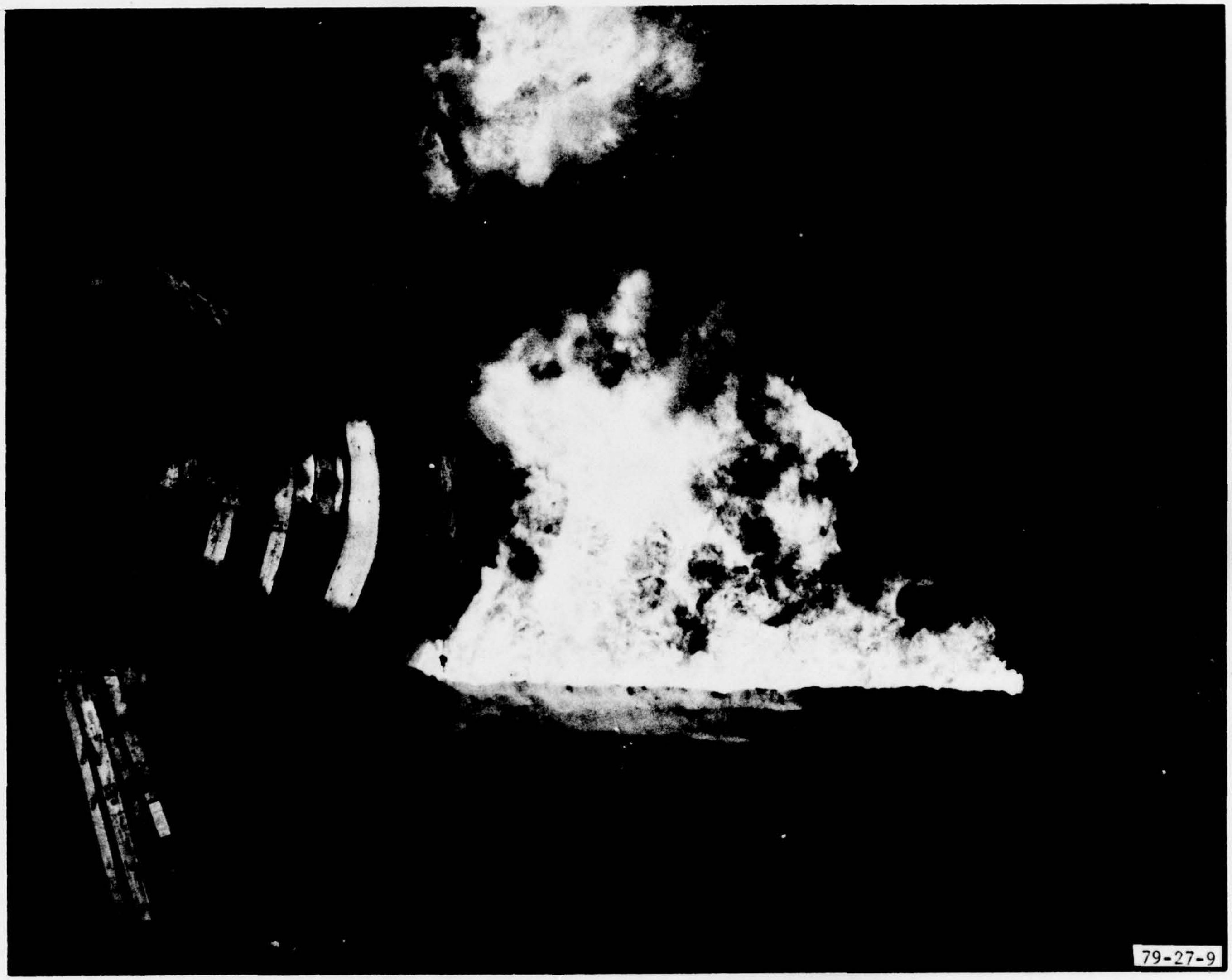

FIGURE 9. CALM WIND CONDITION--TEST 13

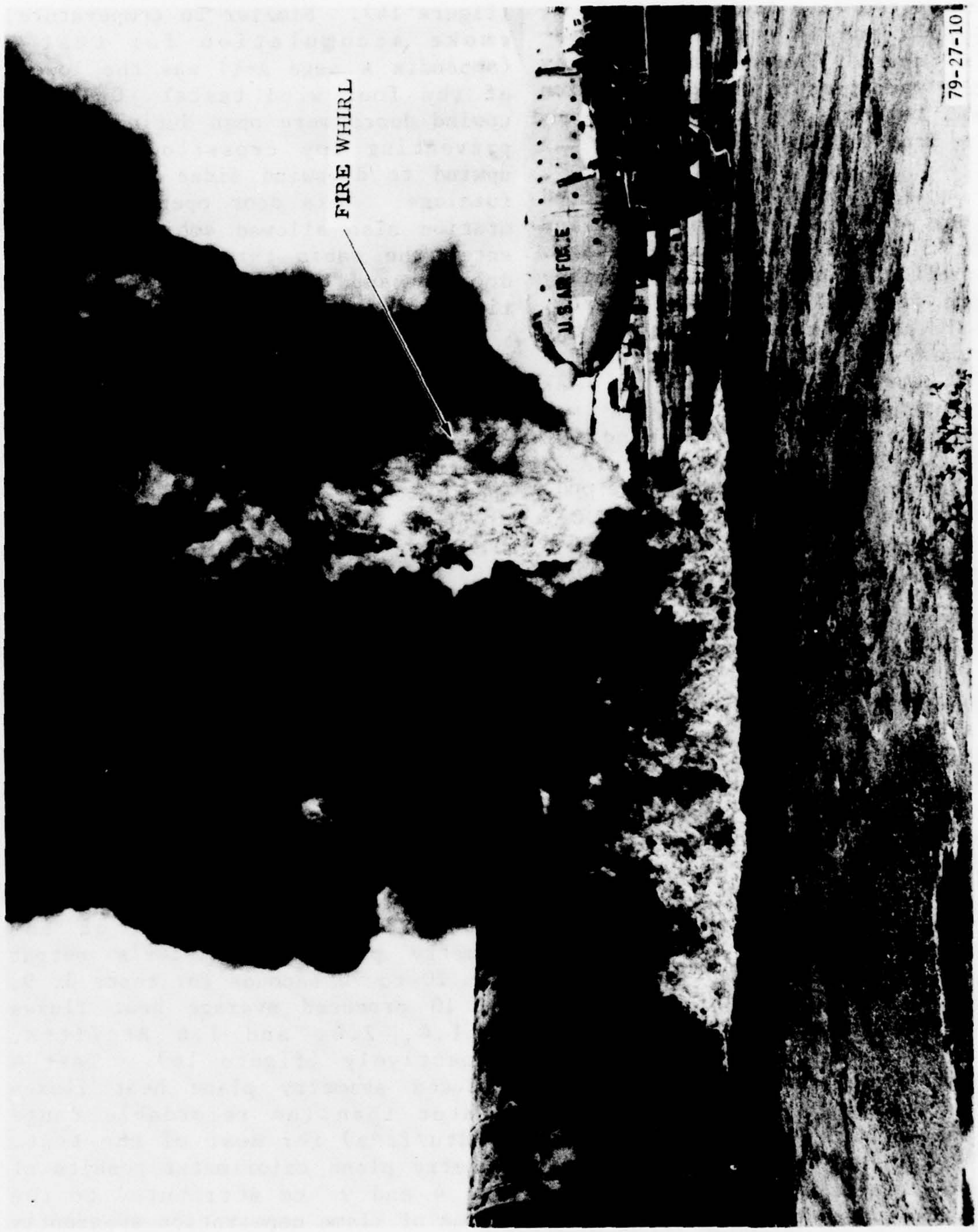

FIGURE 10. FIRE WHIRL--TEST 14

Appendix B contains temperature stratification data during tests 3, 4, 9, 10, 13, and 14 for both thermocouple trees. These plots clearly show the variation in the distribution of heat between the cabin floor and ceiling from test to test.

Tests 3, 4, 9, and 10 were conducted with the wind perpendicular to and blowing the fire toward the fuselage. Wind conditions and exit door configurations differed for the four tests. A graph of T1's output shows the variation in heat accumulation for these tests (figure 11). A peak ceiling temperature of 1,400° F was recorded during test 4 (appendix B page B-3). This severe temperature is attributed to downwind door open (DDO) and the upwind door closed (UDC). Such a door opening configuration caused high cabin drafts carrying vast amounts of smoke and heat to flow through the length of the cabin. It appears that the low-pressure downwind opening draws air and combustion products from the fire door through the cabin. In contrast, in test 3 when the wind velocity was higher than in test 4 but the forward door opening locations were reversed, heating of the cabin air was much lower. In this upwind door open (UDO) case, ambient wind entering the cabin appeared to act like a buffer against the expanding fire gases. Evidence of severe flame penetration during test 4 is apparent in the ceiling heat fluxes which were in excess of 5 Btu/ft^{2}s (figure 12). Light transmission data for the bottom laser (appendix A page A-1) showed smoke accumulation occurring as early as 10 seconds into test 4 and total obscuration of the 3-foot light beam by 25 seconds. Test 3, in contrast, experienced very little flame penetration (ceiling calorimeter plot--figure 13) even though the doorway was observed to be covered by fire during the entire test (figure 14). Similar to temperature, smoke accumulation for test 3 (appendix A page A-1) was the lowest of the four wind tests. Only the upwind doors were open during test 3, preventing any crossflow from the upwind to downwind sides through the fuselage. This door opening configuration also allowed ambient wind to enter the cabin through the forward doorway and block expansion of the fire gases.

The ceiling calorimeter outputs for test 9 (ADO) and test 10 (ADC) are included in figures 13 and 12, respectively. Intermittent flame penetrations occurred during tests 9 and 10. More severe flame penetrations in test 9 produced a higher accumulation of heat (appendix B page B-5) and a more rapid accumulation of smoke (appendix B page B-2) than during test 10. More smoke and heat inside the cabin when all doors are opened as opposed to when all doors are closed, with wind, produced the same trend as with calm wind conditions (figure 5). Figure 15 shows flame penetration during a perpendicular wind test (test 9). The smoke layer is evident near the top of the doorway.

A numerical integration of the symmetry plane calorimeter's output from 20 to 70 seconds for tests 3, 9, and 10 produced average heat fluxes of 1.4, 2.4, and 1.6 Btu/ft^{2}s, respectively (figure 16). Test 4 produced symmetry plane heat fluxes greater than the recordable range (4 Btu/ft^{2}s) for most of the test. Symmetry plane calorimeter results of test 4 and 9 are attributed to the degree of flame penetration apparently controlled by the door opening configuration. During both of these tests, smoke and heat could enter on the

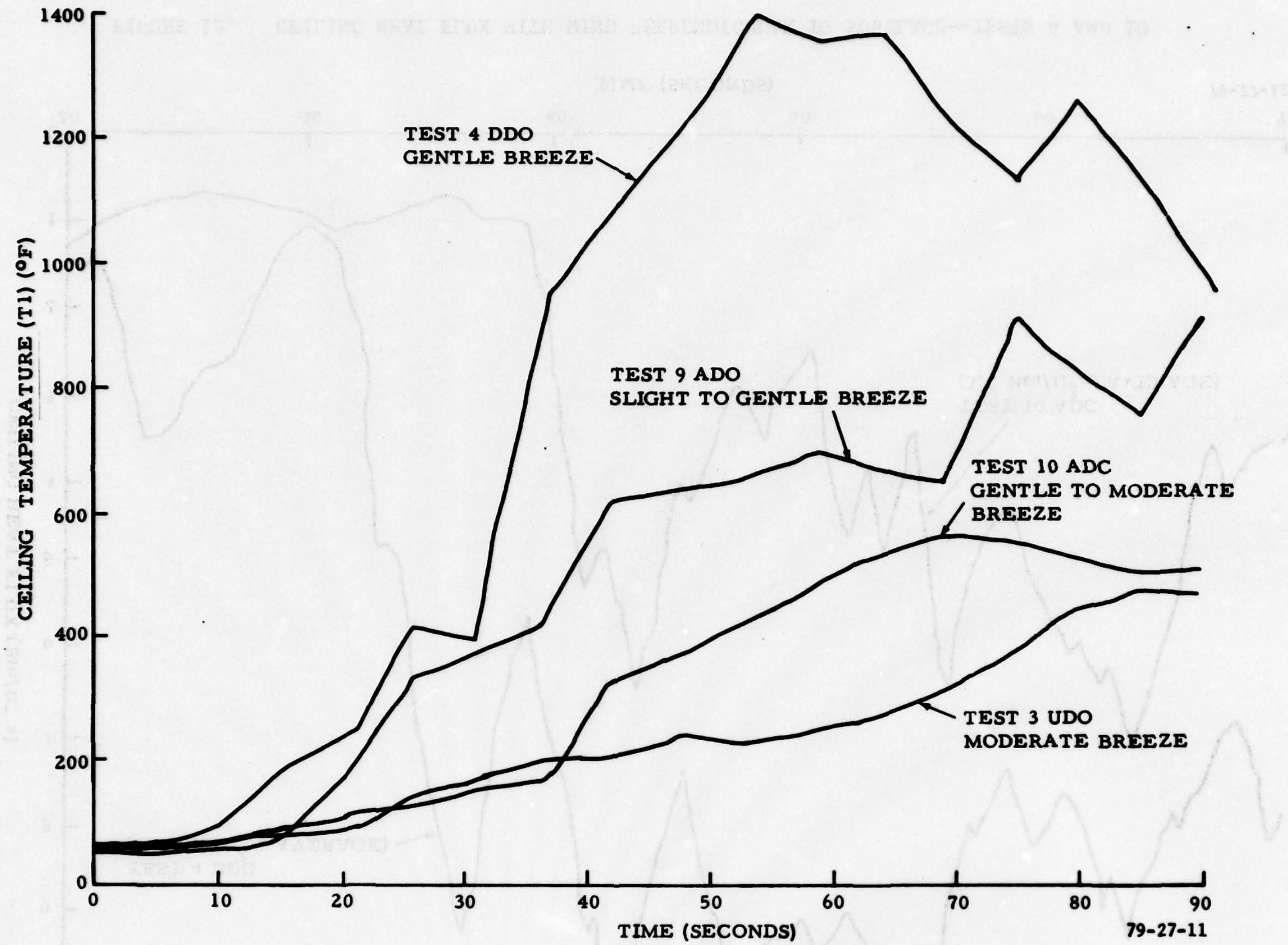

FIGURE 11. CEILING TEMPERATURE HISTORY WITH WIND PERPENDICULAR TO FUSELAGE--TESTS 3, 4, 9, AND 10

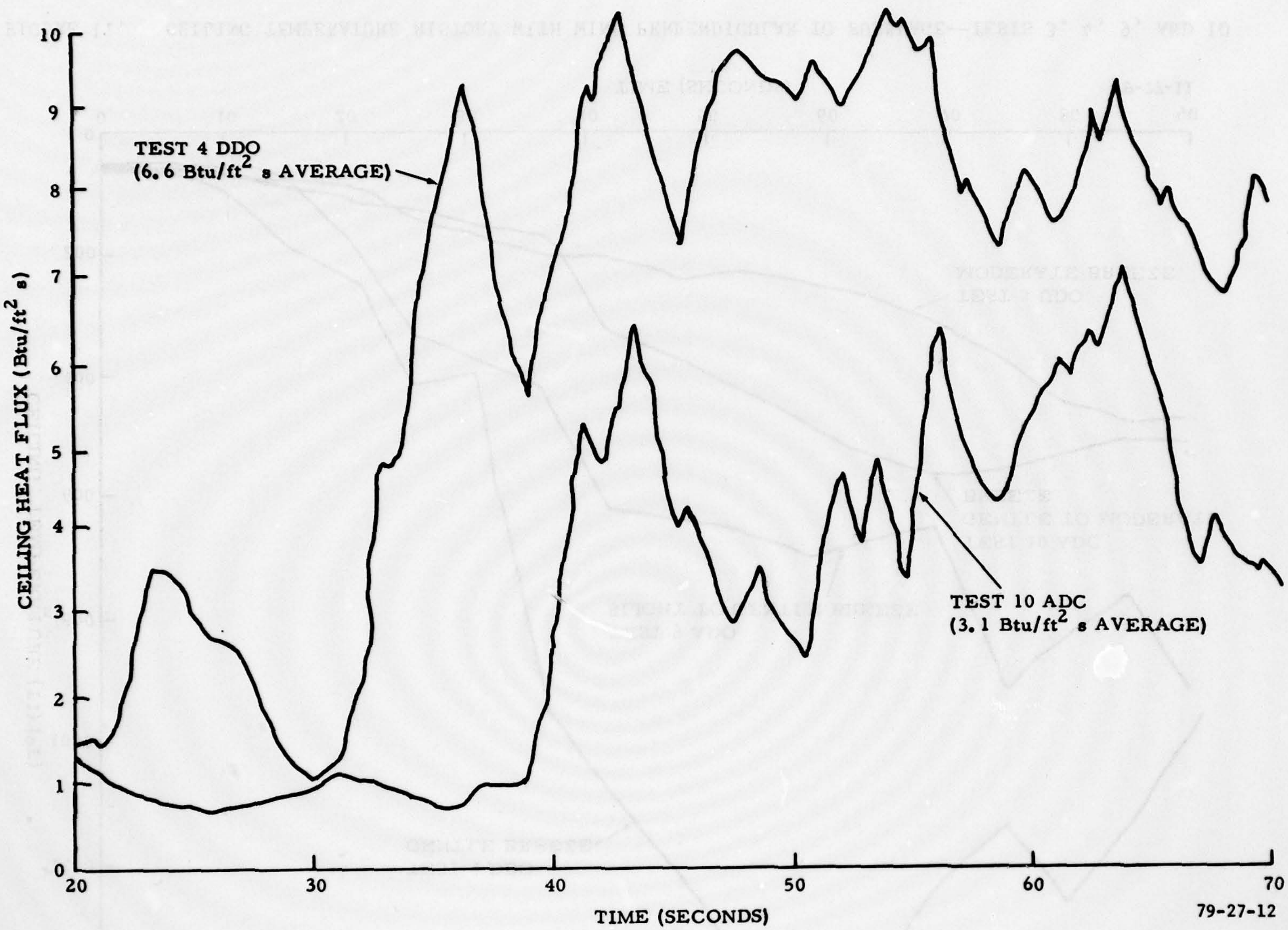

FIGURE 12. CEILING HEAT FLUX WITH WIND PERPENDICULAR TO FUSELAGE--TESTS 4 AND 10

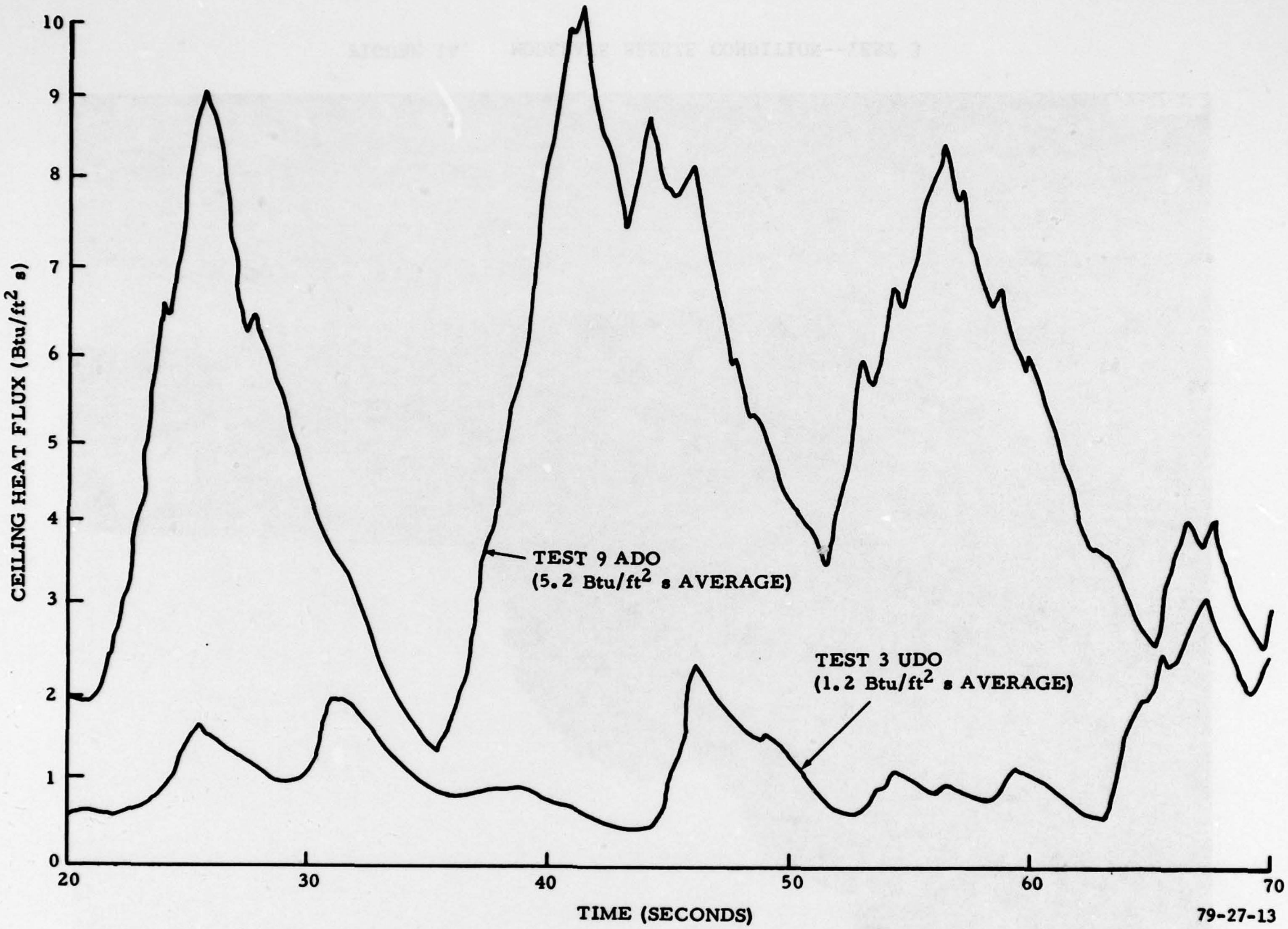

FIGURE 13. CEILING HEAT FLUX WITH WIND PERPENDICULAR TO FUSELAGE--TESTS 3 AND 9

FIGURE 14. MODERATE BREEZE CONDITION--TEST 3

FIGURE 15. FLAME PENETRATION--TEST 9

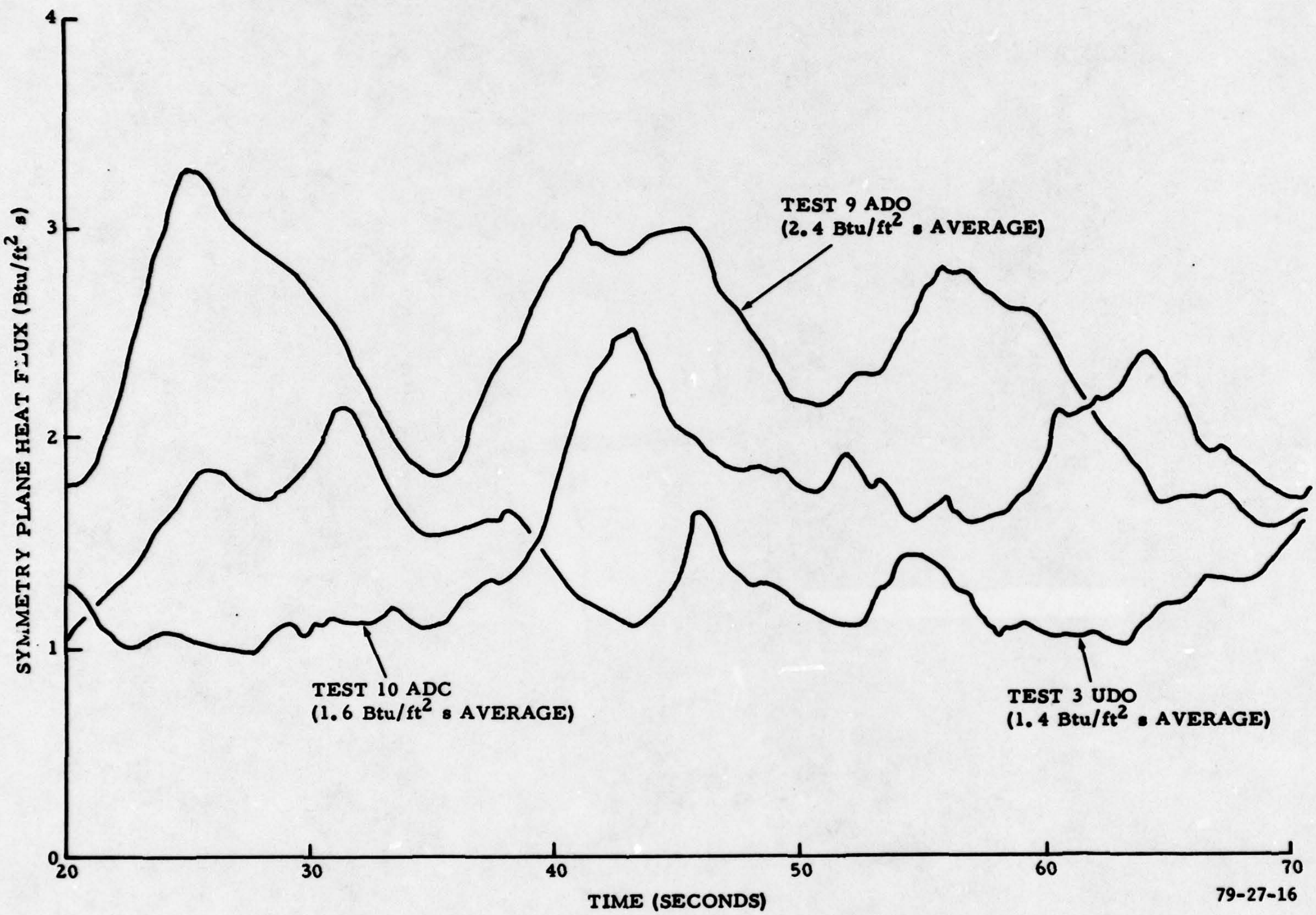

FIGURE 16. SYMMETRY PLANE HEAT FLUX WITH WIND PERPENDICULAR TO FUSELAGE--TESTS 3, 9, AND 10

upwind side and exit on the downwind side of the fuselage. These tests (4 and 9) permitted a "forced" flow through the cabin. However, when the forced flow is blocked (tests 3 and 10), a less severe environment results within the cabin.

Skin Calorimeter (C-3) outputs tended to confirm the observed flame coverage of the fire door during the tests. Low accumulation of heat and smoke corresponded to low skin calorimeter outputs; i.e., similar to those of test 8 (figure 17). The high, steady exterior calorimeter output during test 13 (14 Btu/ft^{2}s) is indicative of consistent flame coverage of the fire door with calm wind conditions. Test 4 produced a similar high exterior calorimeter output; however, the presence of wind caused random fluctuations ($\pm$6 Btu/ft^{2}s) about the 14 Btu/ft^{2}s average.

Table 3 summarizes the relative severity of the two calm wind condition tests and the four tests in which a gentle-to-moderate breeze was blowing the fire toward the fuselage. Excluding tests 3 and 4 (in which varying door opening configuration broadened the possible spectrum of results), the average symmetry plane heat flux falls into a range of 1.6 to 2.4 Btu/ft^{2}s. For the calm wind condition tests (13 and 14), the symmetry plane heat flux falls into a range of 1.8 to 2.4 Btu/ft^{2}s.

Table 3 also includes temperature and smoke hazard data. It is clear from elapsed times to the arbitrary T2 = 200° F and 400° F and L2 = 50 and 10 percent values, that the smoke hazard precedes the temperature hazard in the cabin for these tests. In addition, similar trends in the relative severity are shown for smoke, temperature, and heat flux.

SUMMARY OF RESULTS

1. With the wind parallel to the fuselage, very little accumulation of heat and smoke resulted within the cabin due to incomplete flame coverage of the fire door opening. A test with the fuselage upwind of the fire produced similar results.

2. Tests were conducted with calm wind conditions, in one case with all doors open (ADO) and in another case with all doors closed (ADC). With ADO, the average symmetry plane heat flux was 2.4 Btu/ft^{2}s. With ADC, the average symmetry plane heat flux was 1.8 Btu/ft^{2}s.

3. The heat flux to the external skin calorimeter averaged about 14 Btu/ft^{2}s for calm wind condition or steady, perpendicular wind (blowing fire toward fuselage) tests.

4. Depending on wind direction and speed and door opening configuration, the average heat to the symmetry plane calorimeter at the fire door can vary from 1.0 Btu/ft^{2}s (wind pushing fire away from fuselage) to values in excess of 4 Btu/ft^{2}s (wind driving fire into doorway with downwind door open).

5. Four tests were conducted with a gentle-to-moderate breeze blowing the fire toward the fuselage. Door opening configurations were found to control the flow of heat and smoke into the cabin. The most hazardous cabin environment for these tests occurred when the upwind door was closed and the downwind door was open. Conversely, the least hazardous environment occurred when the upwind door was open and the downwind door was closed. When either all doors were open or all doors were closed,

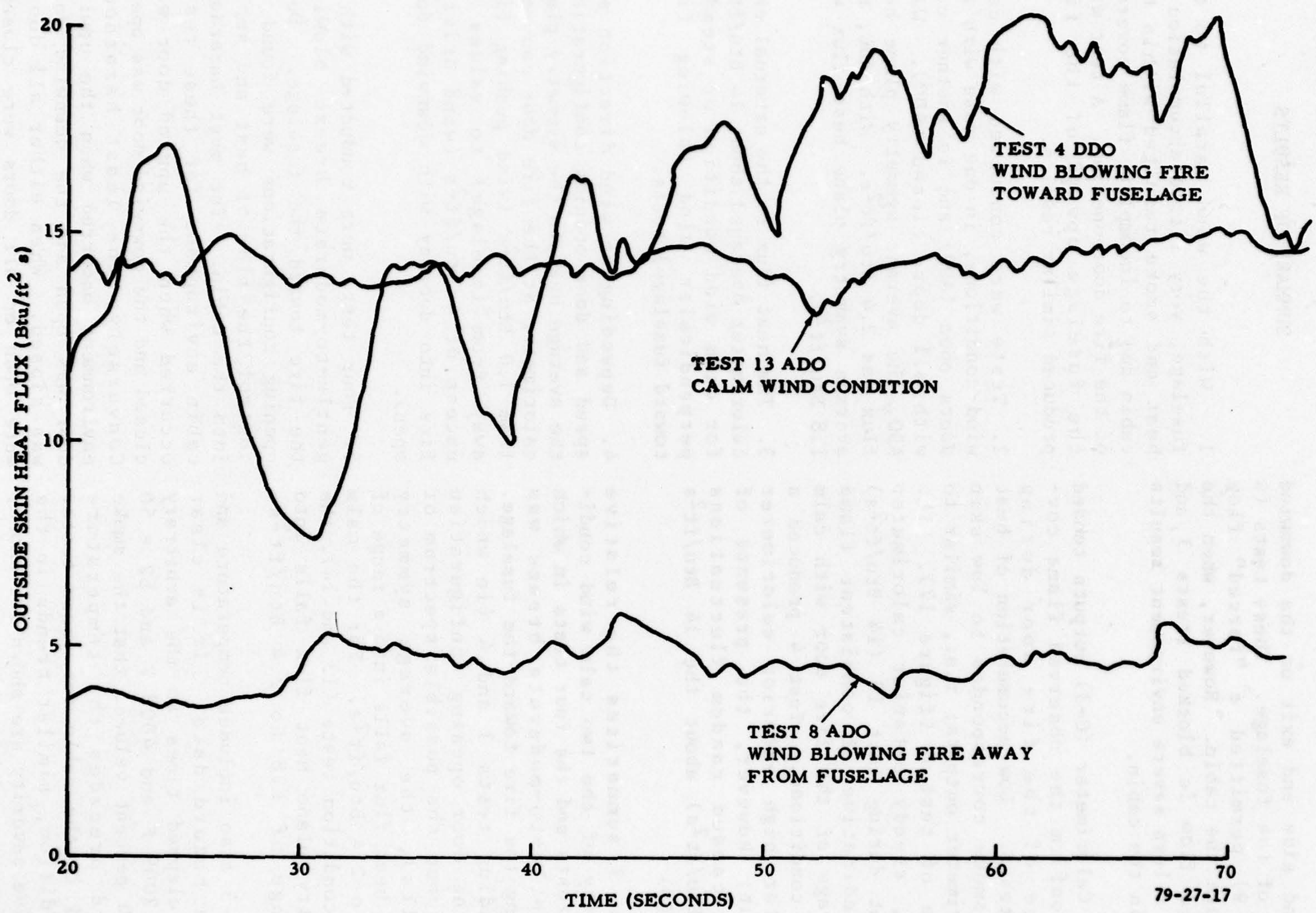

FIGURE 17. EXTERNAL SKIN HEAT FLUX--TESTS 4, 8, and 13

TABLE 3. RELATIVE SEVERITY OF TESTS 3, 4, 9, 10, 13, and 14

Test No.	Door Configuration	Wind Condition	Average Symmetry Plane Heat Flux (Btu/ft^{2}s)	Average Ceiling Heat Flux (Btu/ft^{2}s)	Time In Seconds To Temperature, T2 of 200° F	Time In Seconds To Temperature, T2 of 400° F	Time In Seconds To Light Transmission, L2, of 50%	Time In Seconds To Light Transmission, L2, of 10%
3	UDO	moderate	1.4	1.2	67	na	52	69
10	ADC	gentle to moderate	1.6	3.1	44	68	43	48
14	ADC	calm	1.8	2.5	77	na	56	78
13	ADO	calm	2.4	5.6	50	67	38	48
9	ADO	slight to gentle	2.4	5.2	32	46	26	35
4	DDO	gentle	>4	6.6	23	33	16	19

the hazard appeared between these extremes.

6. Smoke was detected earlier than temperature in the cabin in all tests. Similar trends in the variation of smoke, temperature, and heat flux show that these parameters are related.

CONCLUSIONS

1. Given an external fuel fire much larger than an aircraft doorway, wind direction and door opening configuration play the dominant role in the development of the internal cabin hazard from the pool fire.

2. The symmetry plane calorimeter value of 1.8 Btu/ft^2s found in earlier calm wind modeling tests appears to be a lower bound for full-scale tests using the same geometrical door size to fuselage diameter ratio. This symmetry-plane calorimeter value will go up with increased flame penetrations.

3. Comparison of the different tests demonstrates that increased fire penetrations shown by the ceiling calorimeter result in corresponding increases in the smoke and temperature hazards.

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APPENDIX A

LASER TRANSMISSOMETER DATA FOR BOTTOM LASER (L2) TESTS 3, 4, 9, 10, 13, AND 14

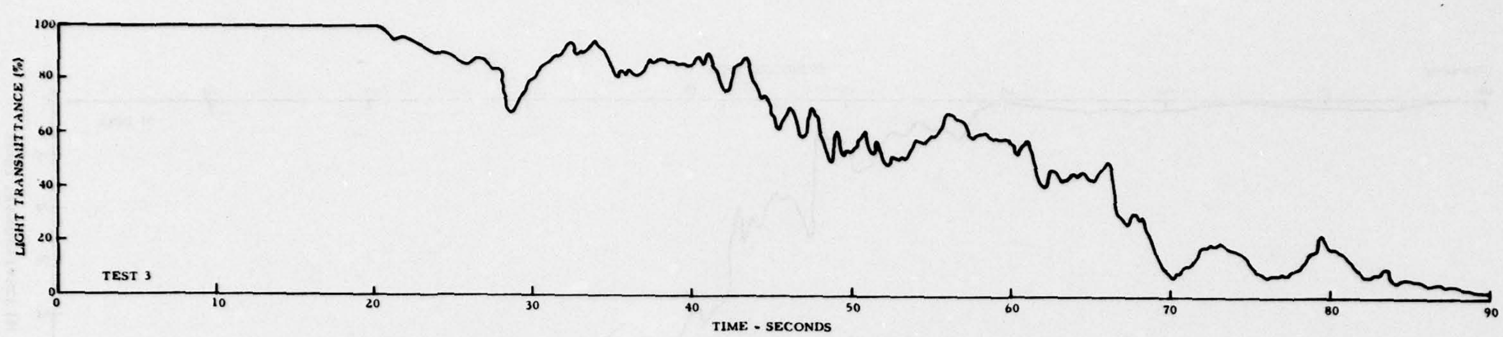

FIGURE A-1. TEST 3

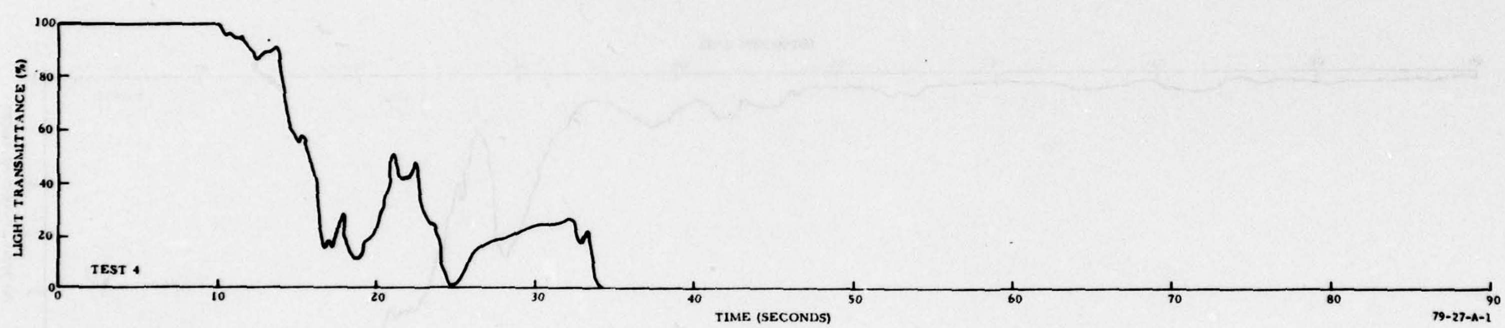

FIGURE A-2. TEST 4

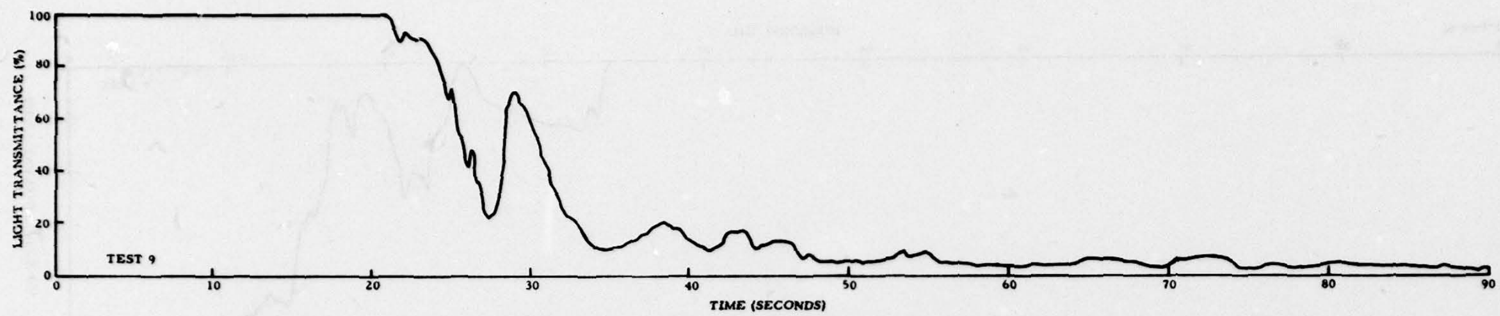

FIGURE A-3. TEST 9

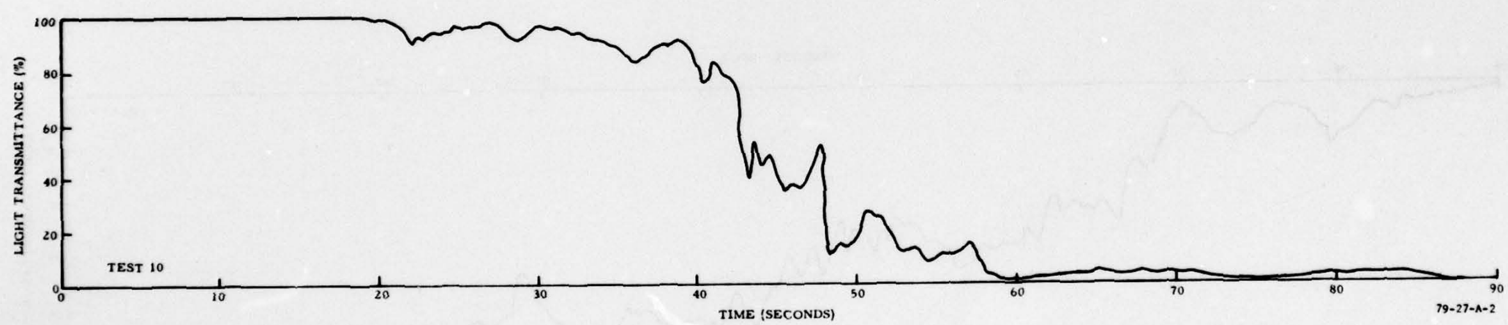

FIGURE A-4. TEST 10

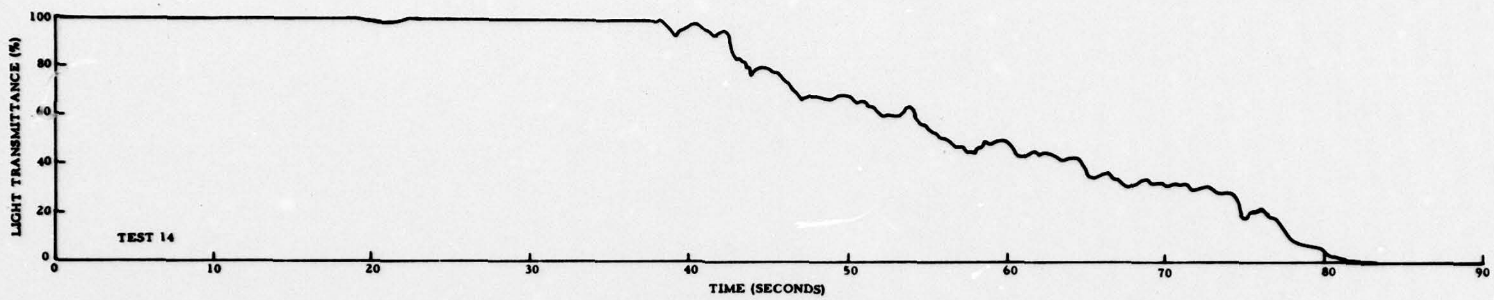

FIGURE A-5. TEST 14

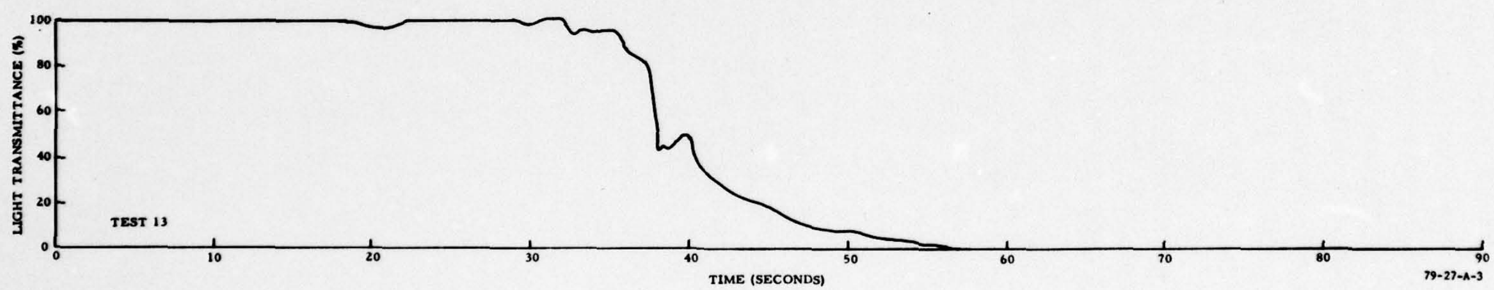

FIGURE A-6. TEST 13

APPENDIX B

TEMPERATURE STRATIFICATION PLOTS

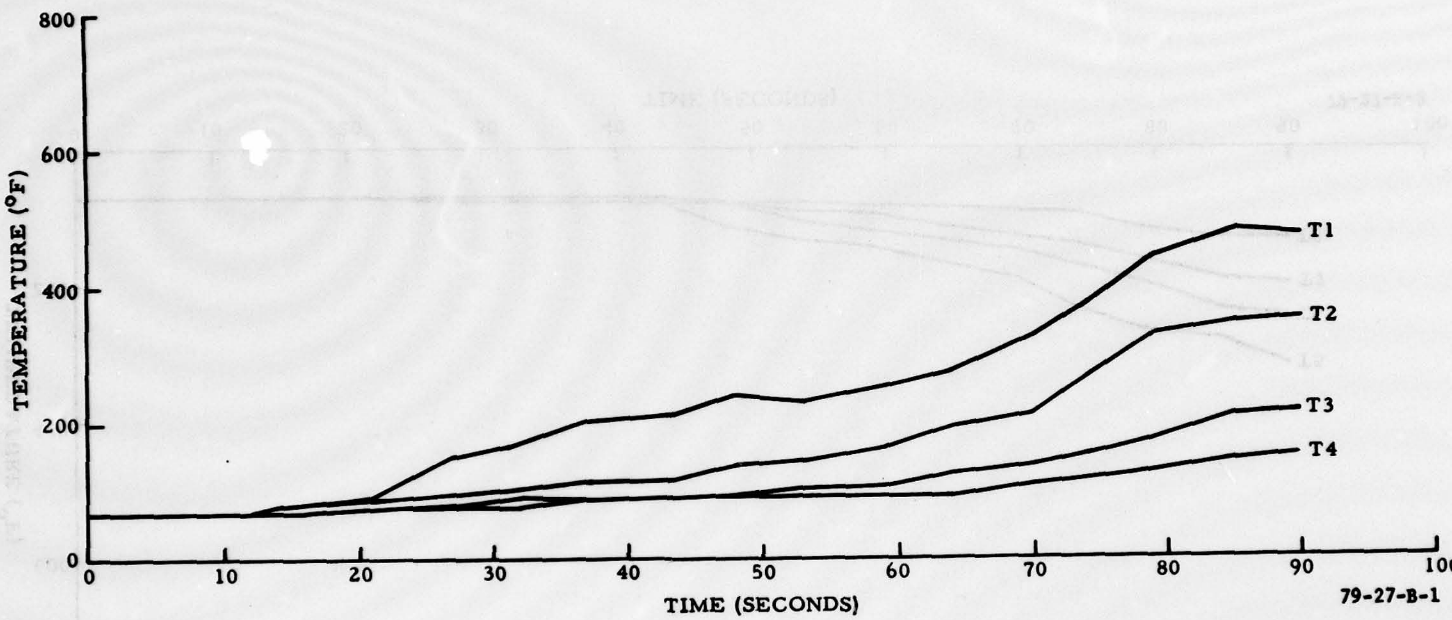

FIGURE B-1. TEST 3

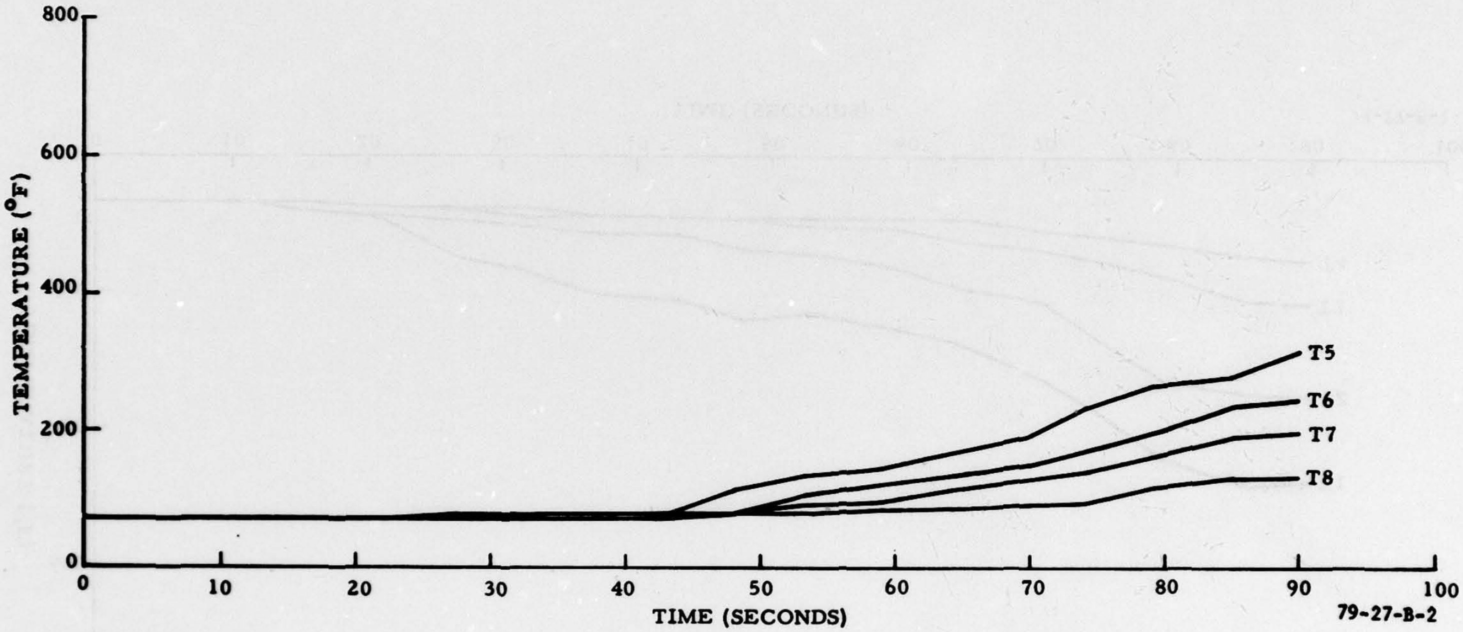

FIGURE B-2. TEST 3

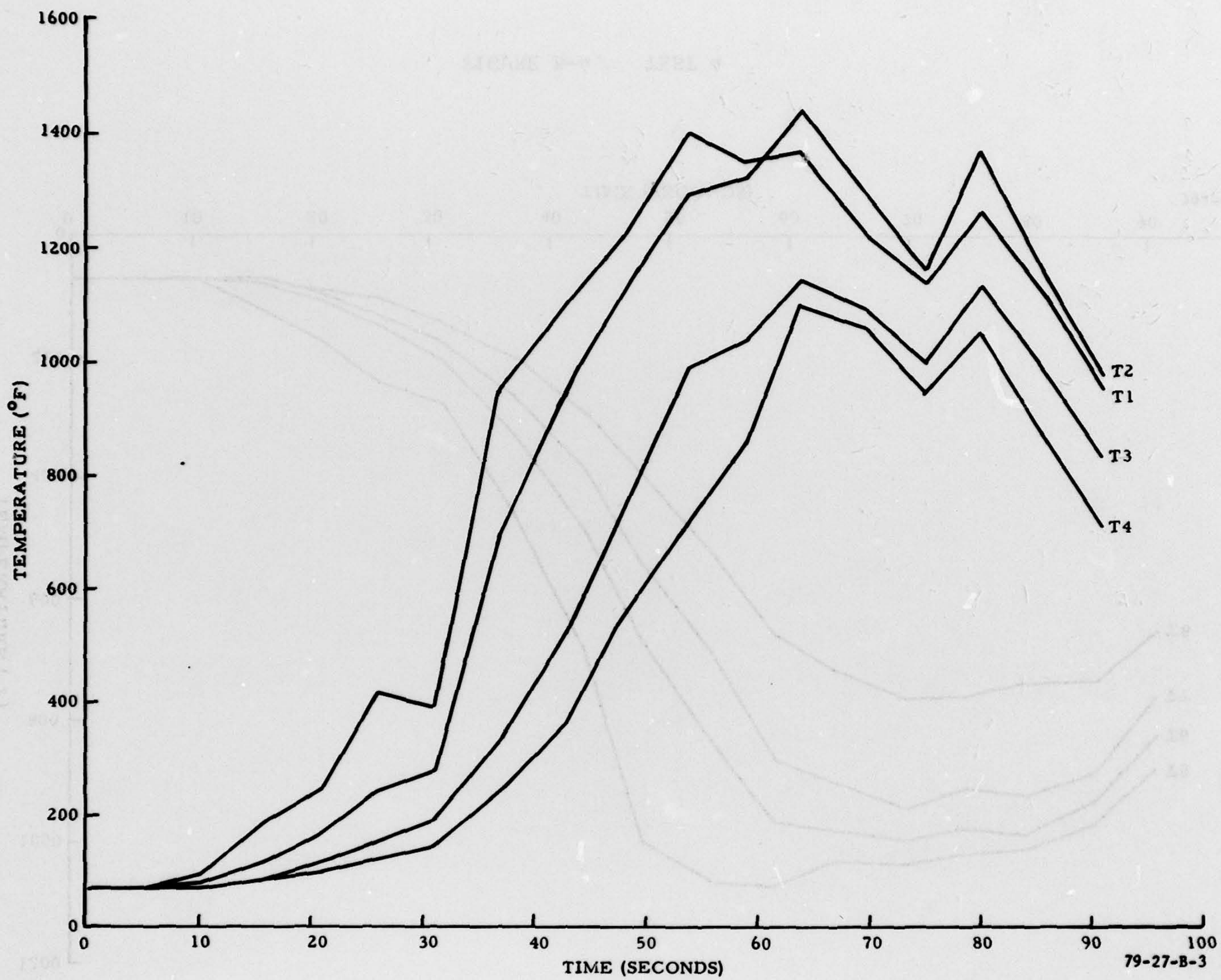

FIGURE B-3. TEST 4

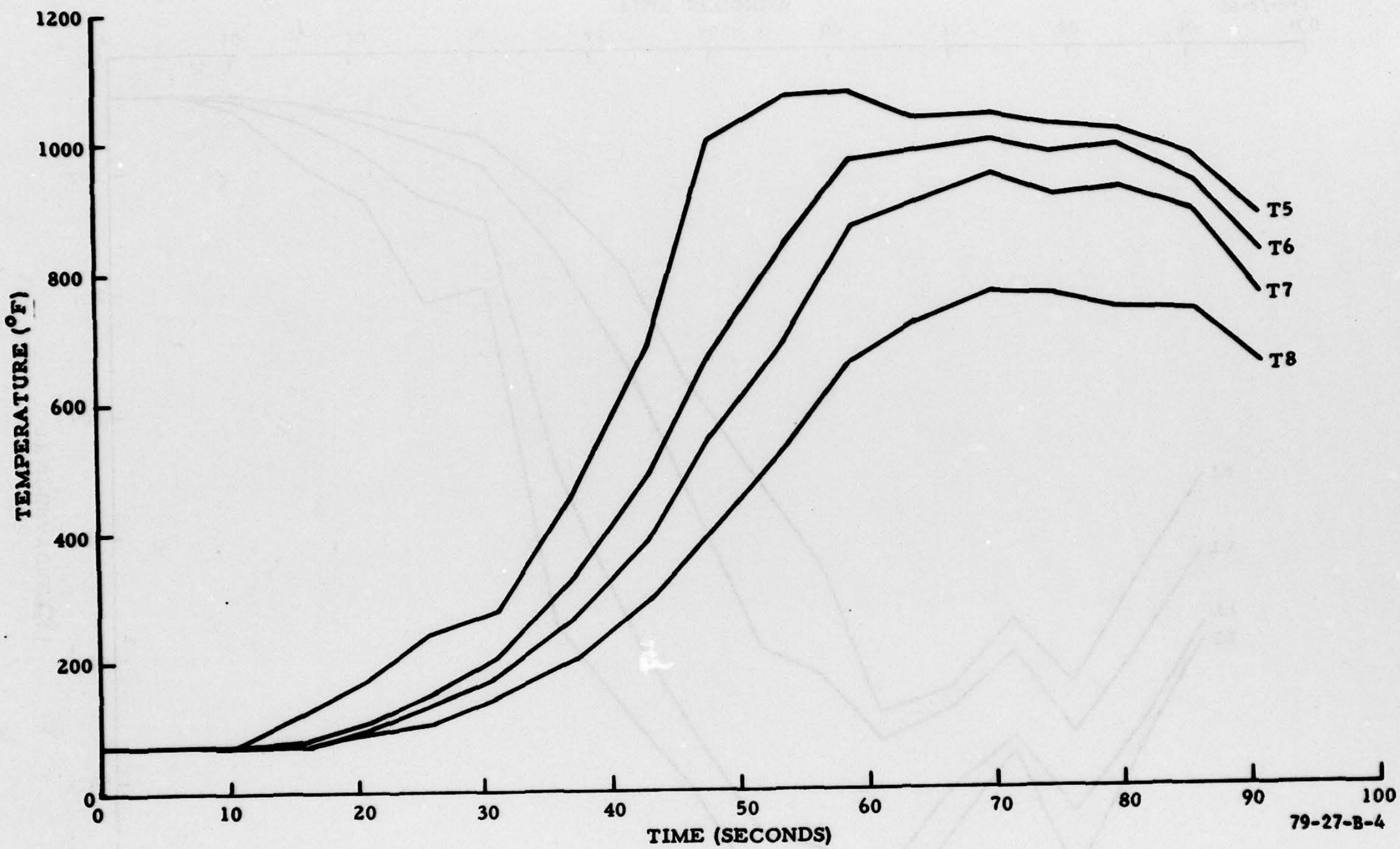

FIGURE B-4. TEST 4

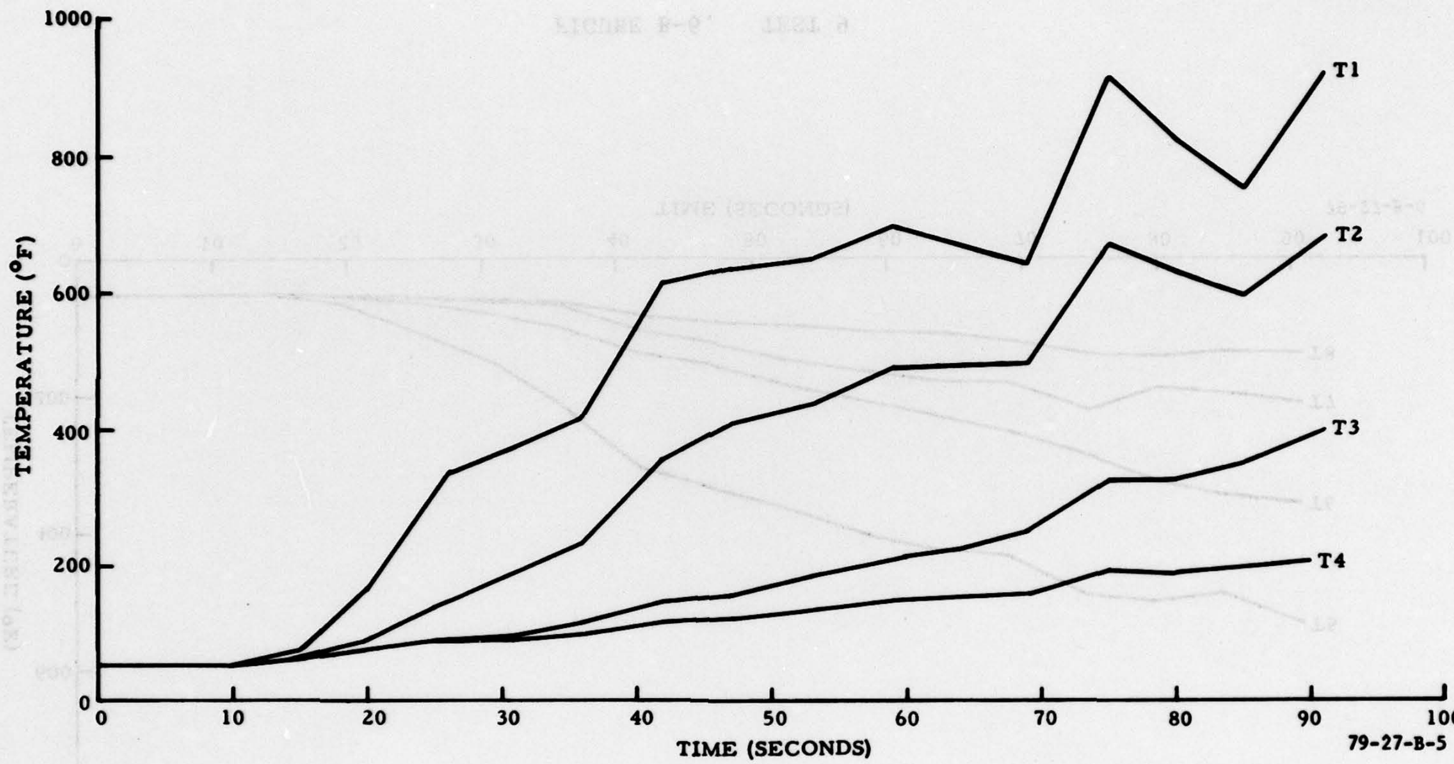

FIGURE B-5. TEST 9

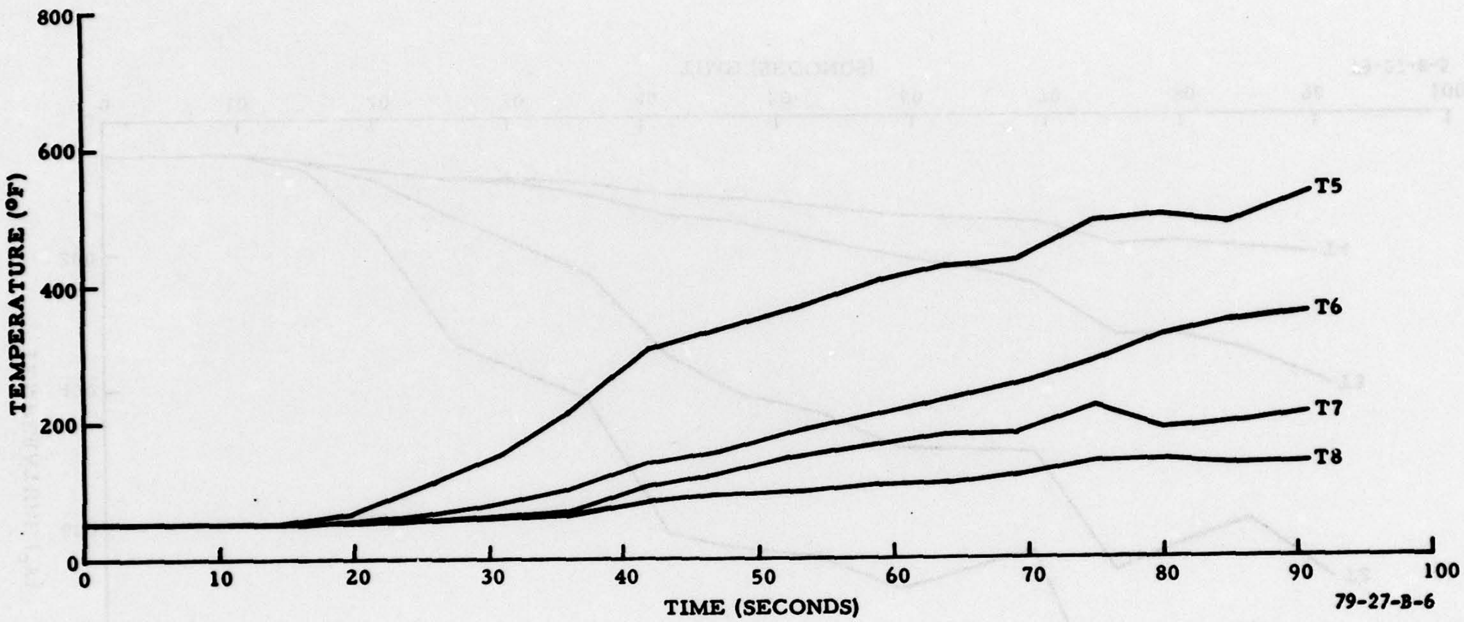

FIGURE B-6. TEST 9

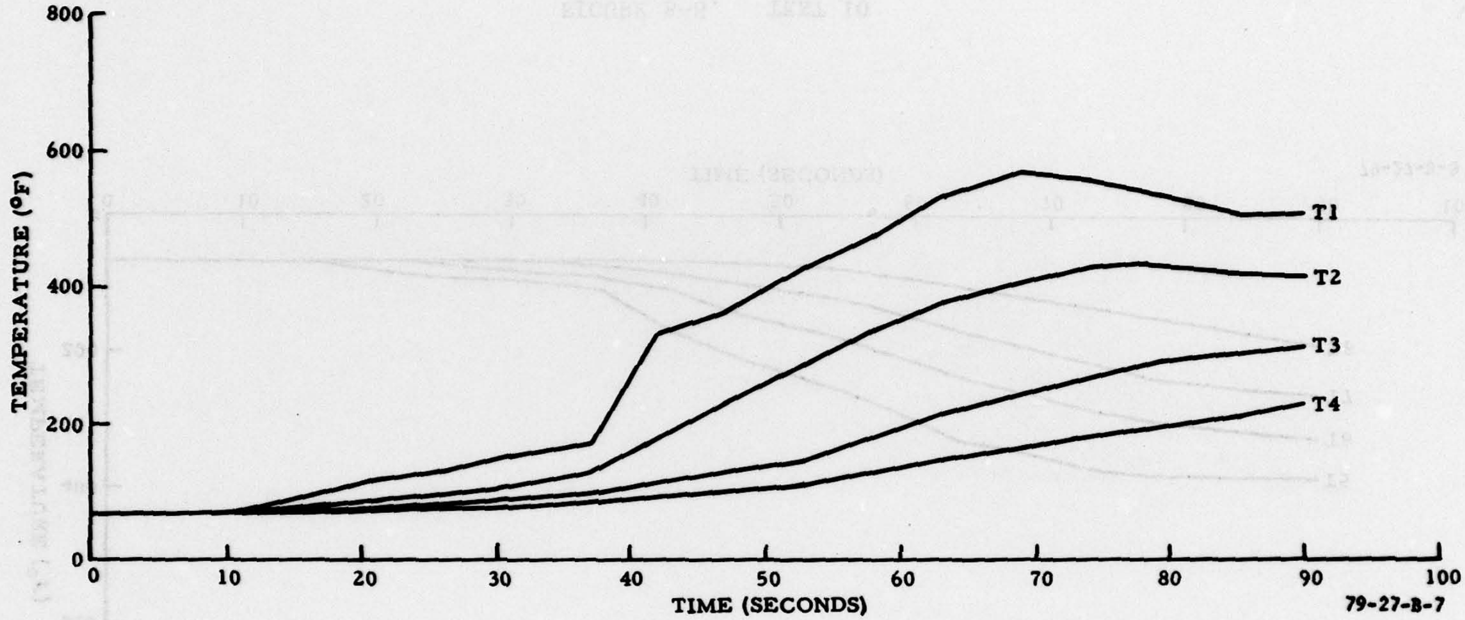

FIGURE B-7. TEST 10

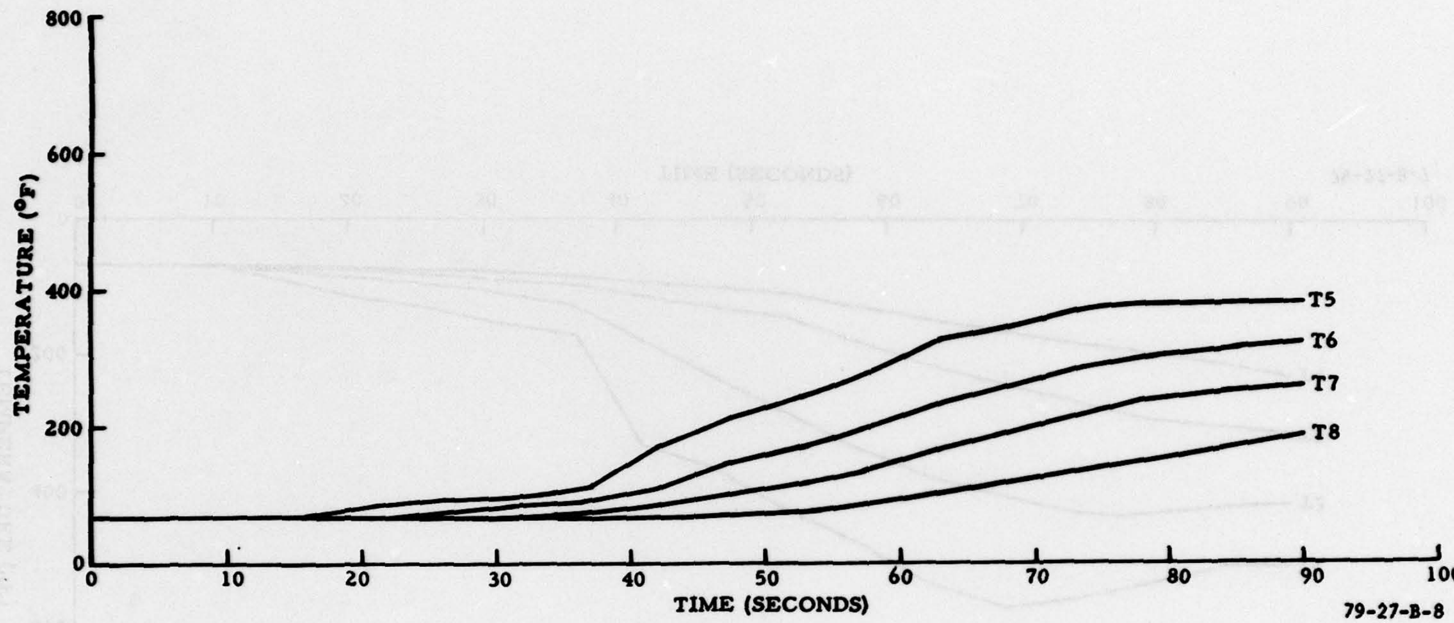

FIGURE B-8. TEST 10

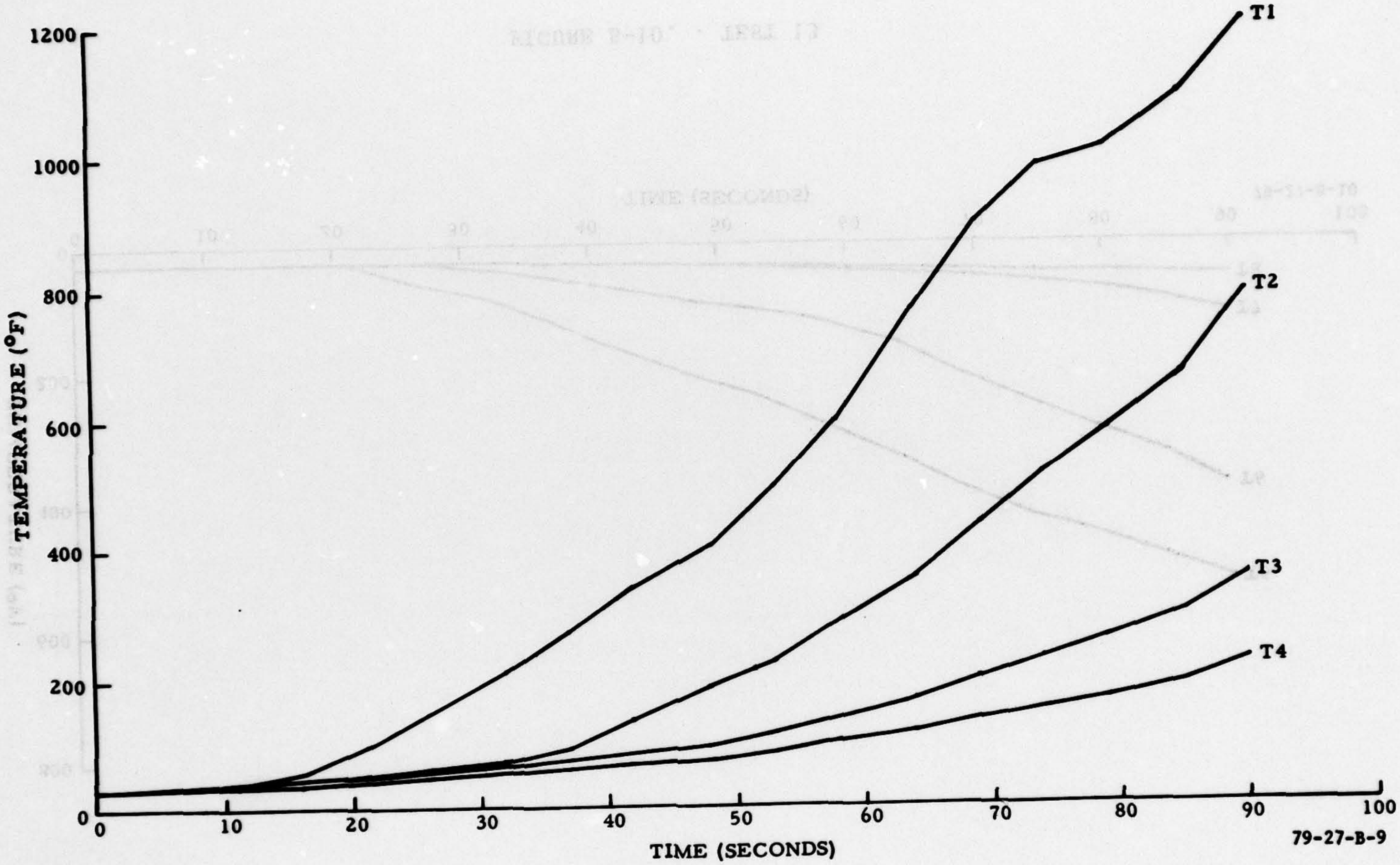

FIGURE B-9. TEST 13

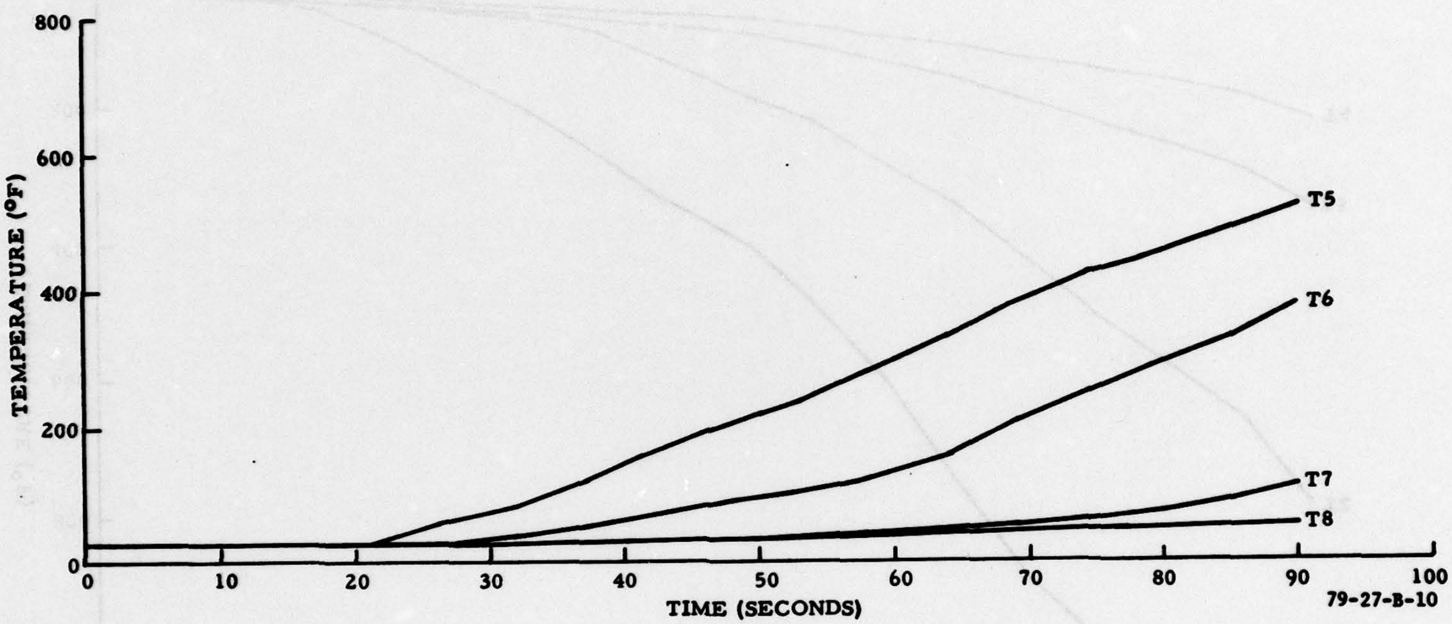

FIGURE B-10. TEST 13

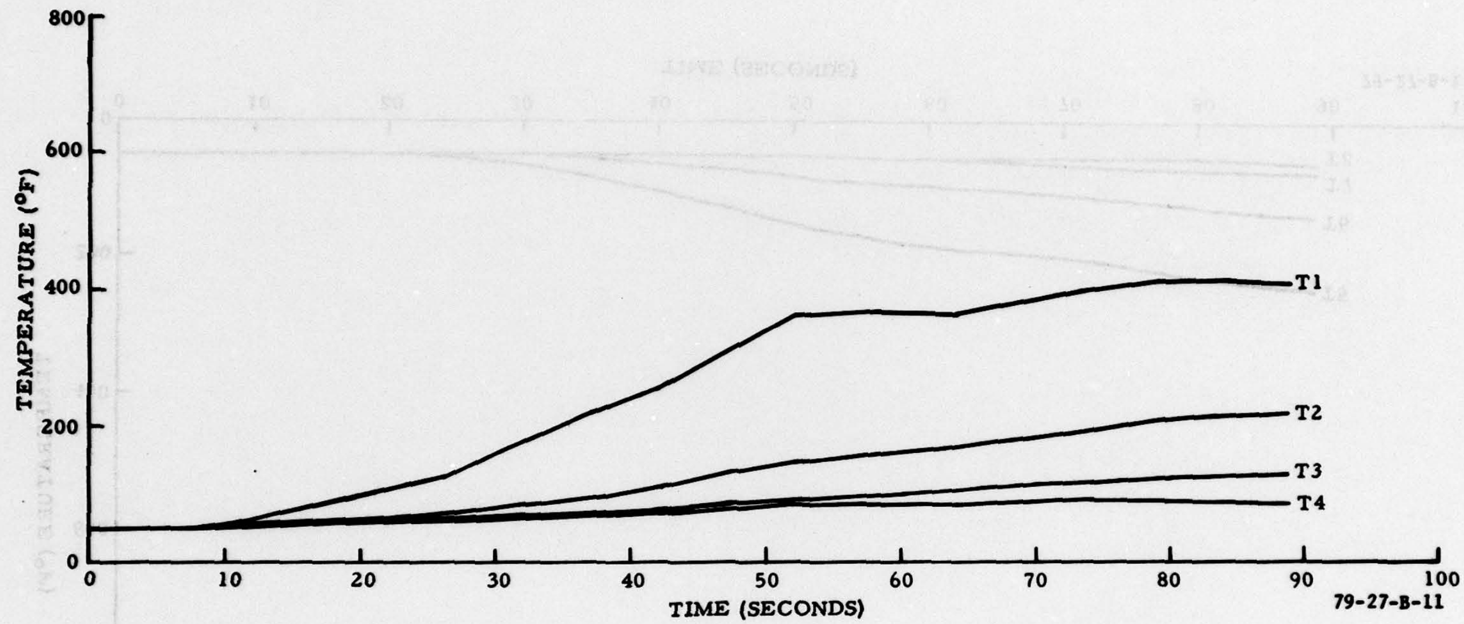

FIGURE B-11. TEST 14

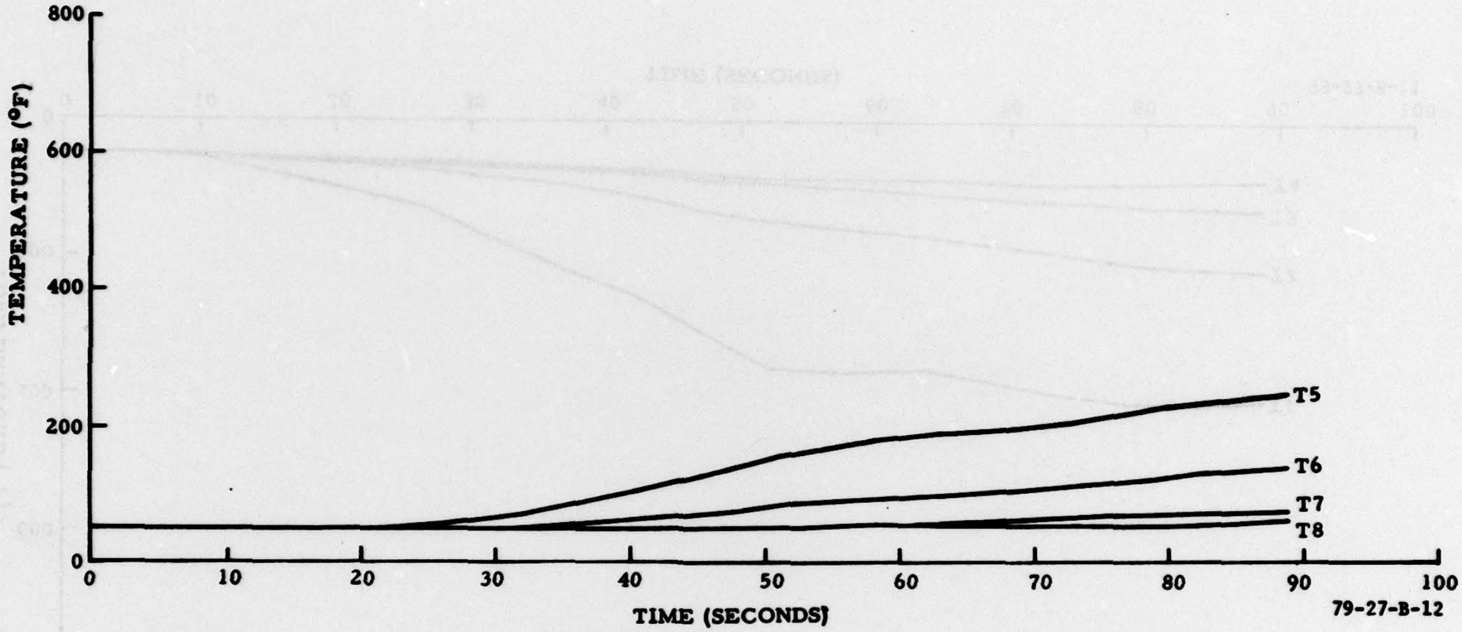

FIGURE B-12. TEST 14